MODERN

Operative Bone Surgery

WITH SPECIAL REFERENCE
TO THE

Treatment of Fractures

BY

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WITH 120 ILLUSTRATIONS

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DEDICATED

TO THE

MEMORY OF THE HIGHLY ESTEEMED

AND BELOVED

JOHN B. MURPHY

PREFACE.

THE great demand for a comprehensive, yet abridged, book on "Plastic Bone Surgery" suitable for the busy surgeon, presenting clearly the modern methods and mechanical means for perfecting such work, has been firmly impressed upon the mind of the author in the last three years by the great number of inquiries from this and foreign countries for a book dealing with this subject. It was with a keen appreciation of this demand that the present volume was undertaken.

Following these ideas, the author has endeavored to give the facts in autoplastic bone work and the modern instruments used in such work as briefly as is compatible with clearness.

It has been a difficult task, because there is no similar work on this subject published up to the present time. All previous publications on bone surgery are largely composed of reports of cases.

The transplantation of bone is not an entirely new procedure, and the advent of asepsis and the development of the electro-operative motor instruments have made possible its extensive application. The dependable methods of obtaining asepsis in bone surgery must withstand the closest detailed scrutiny.

Bone being a connective tissue, lends or gives itself favorably to transplantation, and to the repair of defects and deficiencies of the skeleton. It is the only safe and reliable internal fixation. By the use of autogenous material the surgeon follows nature's own method, and is thereby able to overcome mechanical surgical defects which hitherto he was unable to deal with successfully.

The application of external fixation-braces, and the uncertain extemporizing methods, cannot compare with the autogenous bone-graft accurately and directly implanted.

The reader will recognize, after a careful review of the voluminous literature of the last few years, the difficulty of justly estimating the value of conflicting opinions; therefore, a judicial and careful selection from the vast material is the most important duty of the writer.

The author is deeply indebted to the late John B. Murphy for the privilege of selecting from his extensive library valuable röntgenograms, many of which are used in this volume, and also for his many suggestions.

The author is also obligated to Dr. Arthur H. Hertzler for his most valuable criticisms and corrections.

C. G.

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INTRODUCTION.

In the Library at Leipsic is the celebrated hieratic medical papyrus which was discovered by George Moritz Ebers, a German Egyptologist and novelist, born in Berlin in 1837. While travelling in Egypt in 1872 he discovered the hieratic medical papyrus which is now known as the "Papyrus Ebers," which dates back one thousand and fifty-five years B.C. It is one of the best preserved Egyptian papyri in existence, and forms the chief source of information in regard to the medical knowledge of the ancient Egyptians.

It is evidenced by these ancient records that rhinoplastic operations were performed then by the flap method. The ancient Hindoo specialists made new noses from the frontal tissues long before the time of the noted Italian surgeon, Taliacotius. The Hindoos replaced the cartilage portion, cut off as a punishment for adultery or other reasons, by a cutaneous flap, turned down from the forehead. Taliacotius, in the sixteenth century, made noses and lips from the tissues of the arm; he thus improved the features resulting from disfigurement in war, or by disease, many years before the days of Dieffenbach.

Plastic or reconstructive surgery has made wonderful strides since its revival, in the first half of the nineteenth century, by Dieffenbach and

his contemporaries in Europe, and Muetter and his followers in America.

The development and history of this branch of our art is as attractive as that of aviation. Both would easily evoke in one's mind a pleasure akin to that responding to the touch of a novelist's pen.

Wolff, the noted Scotch surgeon, was able to convince a few of his profession that a free flap or graft of skin taken from a distant portion of the body could be successfully transplanted to correct eversion of the eyelid.

His method of dissecting up the ectropion, replacing the eyelid, and filling the raw gap with a piece of detached skin, was often tried, but this operation failed too frequently to become a standard procedure.

Then came another celebrated Scotchman, Lord Lister, who died but a few years ago, and who did so much to improve surgical operative technic by developing and demonstrating the importance of asepsis in surgical work.

Krause, of Germany, then came forward, who developed the usefulness of the free flap or graft of Wolff, by using it in general surgery, and safeguarding it with an antiseptic technic.

Experimental research and clinical observation have proved that all tissues are governed by physiological laws, the same as those regulating the cell-life and cell-death of the skin. Thoughtful men with broadened minds during the past half century have demonstrated fully that all tis-

sues—teeth, tendons, blood-vessels, nerves, fascias, cartilage, and bone—may be removed from one portion of the body and transplanted to another, and live and grow and become a part of the tissue in which it is transplanted. The patient's own tissue is far superior to that of any other individual for these operations. The tissue from a young person lives and grafts more readily than from the aged.

To Dr. Ollier, of France, should be given great credit in the field of orthopedic surgery, for it was his work, and the stimulus which he gave to the profession, that established the possibility of using bone in plastic operations. It is almost fifty years since Ollier first gave special attention to this branch of surgery.

The wonderful development now seen in osteoplastic work exceeds the march of progress found in other branches of surgery. The methods of Ollier have been modified by the result of increasing knowledge and the invention of modern electro-operative instruments suitable for such work.

Honorable mention, since Ollier's time, is due Tomita, Grohe, Morpurto, Macewen, Axhausen, Murphy, Janeway, Hibbs, Albee, and others, who have done much clinical and experimental work in osteoplastic surgery.

In this volume, only the autogenous bone transplant will be considered, for it is THE safe and sound procedure.

CHARLES GEIGER.

CHAPTER I.

Histology of Chondrin. Cartilage.

In studying the histogenesis of cartilage and bone, the fact is revealed to us that there are still a number of disputed points in regard to the formation and structure of these tissues.

I shall deal as lightly as possible with the minute cellular changes that take place in the regeneration of cartilage and bone; however, there are certain fundamental points that must be described.

Both of these tissues, cartilage and bone, when fully developed, are very easily distinguished from one another, and there is nothing to suggest that they have a close developmental relationship. Cartilage is flexible, smooth, cuts easily, and has a glistening surface and a homogeneous structure; bone is firm, very difficult to cut, and has a tough, irregular surface, with a complex architecture. Microscopically, cartilage cells are situated in a uniform ground substance, of a singular type, varying only in size and shape; large and round in the center, small and flat towards the periphery, where they gradually pass into a surrounding membrane, called the perichondrium.

Microscopically, bone-cells are of various types; in the center is the complex marrow, beyond which is the cortex, made up of characteristic bone-cells, lying in a uniform ground substance.

The entire structure is surrounded by a thin membrane, called the periosteum.

The embryological origin of cartilaginous bone, its close relation to cartilage, is apparent, as it arises from a blastemal-syncytium of white fibrous tissue, and it passes through an intermediate cartilaginous stage.

The chief problems to be considered are, the relative importance of the original cartilage, and the perichondrium in forming the new cartilage.

The histogenesis of bone reveals the fact that there are a number of disputed points regarding the method or methods of its formation; in this, the chief problems to be considered are the relative importance of the original bone and the periosteum in forming the new bone. In the transformation of cartilage into bone the perichondrium takes a very active part in the endochondral ossification. Following the penetration of the perichondrial buds into the cartilage, changes take place by which the marrow cavity and cancellous bone are formed. The exact manner in which the cartilage is formed into bone has not been fully ascertained. Some investigators think that there is a direct change of cartilage-cells into bone-cells; others believe that the new bone is formed outside the old cartilage, which only acts as a direct framework for the new bone. However, with the change within the center of the cartilage co-incidentally there is a direct deposition of bone beneath this perichondrium.

After the bony stage has been reached, the

perichondrium becomes the periosteum, and the chondroblasts become the osteoblasts. Thus, it is believed that there is a very close relation between the perichondrium and the periosteum, between the chondroblasts and the osteoblasts, between the cartilage and the bone; and it would only be natural to expect a certain parallelism in the methods of regeneration of two tissues so closely related in their development.

The perichondrium is the thin membrane which can be separated from the underlying cartilage, providing the exact line of cleavage is found at or near the chondro-osseous junction. It becomes thicker and more adherent, and so continues with the periosteum. Without the microscope it is impossible to make out any separation between the perichondrium and the true cartilage.

The outer layer of the perichondrium consists of a loosely arranged fibrous tissue, beneath which are longitudinally placed plate-like nuclei. In the next layer the nuclei are large, oval in shape, and, when stained, lighter in color, and are not so close together. These latter nuclei shade off gradually into a group which are slightly larger, and have a more vascular appearance; many of the latter are in pairs, as though they were divided.

There is a general idea that cartilage possesses only slight power of regeneration, and it is even held by some that this power is entirely lacking. The greater number of investigators admit that cartilage has the property of regeneration, but

there is no uniformity of opinion as to the exact manner.

The consensus of opinion is that the regeneration takes place from the perichondrium; the transformation from the fibrous connective tissue to the simple cartilage and the complex bone involves as intricate a developmental problem as is met with in any of the developmental changes within the body.

In the study of cartilage and bone it will be noticed that certain cells possess the inherent tendency to produce these specific types of tissue; and although we cannot hope to determine what that stimulating factor may be, we should at least be able to arrive at a uniform interpretation of the various steps of the process.

Here, as in all other regenerative and developmental changes, some unknown factor or forces initiate the transformation that takes place. This influence is often referred to as the inherent organization of the germs, but as yet no one has any definite conception as to what that organization is.

In the early development of the fœtus, many of the cells of the somatic and splanchnic mesoderm are transformed into what is known as the mesenchyme. The mesenchyme is the forerunner of connective tissue. These tissues are intimately associated with the formation of all the organs of the body, and also become definite membranes, cords, or solid masses, etc., *i.e.*, fascia, tendons, ligaments, cartilage, and bone.

CHAPTER II.

Histology of Periosteum and Bone.

Bone may form either from fibrous tissue, in which case it is known as intramembranous bone, or it may develop from cartilage, as in intermedial stage, and then it is known as intercartilaginous, or endochondral, bone. In either case, it is developed from mesenchyme, but differs from other mesenchymatous derivatives in that bone is never of primary formation, either developing in preformed fibrous tissue or cartilage.

In the intramembranous development, when the inherent organic power of the organism stimulates the fibrous tissue to become differentiated into osseous tissue, certain cells, known as osteoblasts, deposit calcium salts in the fibrous tissue matrix, forming a network of bone spicula. These spicula, as development continues, increase in thickness, and extend farther, radiating in all directions, into the connective tissue matrix.

Later on, the cells of the mesenchyme, which are directly adjacent to the reticular plate of bone, previously produced, are seen to condense, and form "a stout membrane". This membrane becomes what is known as the periosteum. By the time the periosteum becomes recognizable as a distinctly condensed membrane, a layer of osteoblasts arrange themselves in a more or less defi-

nite manner between the periosteum and developing bone.

Being limited externally by the fibrous tissue membrane, the osteoblasts deposit a lamella of compact bone. The histological structure of the periosseous layer is intimately associated with the function of the periosteum; its component cellular elements increase or decrease, numerically, directly with the physiological or pathological variation of its function.

In adult bone, its function is slightly different from that of young bone, and extremely variant from that of irritated bone.

Bone is not a simple crude mass resulting from the calcification of cartilage or fibrous tissue. It is a highly developed form of connective tissue. It is in reality a white fibrous tissue, calcified and structurally modified until it becomes osseous tissue. It is distinctly a different structure, the constituent parts of which are arranged systematically.

Two distinct varieties of bone exist; compact, or dense bone, and loose, spongy or cancellous bone. Dense bone is compact, and is always found upon the exterior part of the bone-tissue. Even this apparently compact bone is porous. It differs from spongy bone only in its greater density, and in the arrangements of its osseous substances into lamellæ. It particularly forms the shafts of the long bones, and constitutes the outer portion of their extremities, and of the short, flat and irregular bones. Excepting the dentine and

enamel, it represents the hardest substance of the body. It is elastic and tough, and much force is required to break it. All bones possess two membranes; the covering or periosteum, and the lining or endosteum. The periosteum is a dense tissue, which is firmly attached to the bone by trabeculæ of fibrous tissue (Sharpey's fibers), which penetrate the bone at right angles to its surface, and carry blood-vessels into the dense bone. They do not directly enter the Haversian system, but only circumferential and intermediate lamellæ—parts that are formed by periosteal action. Some of these vessels, however, communicate with the Haversian canal, and even with the endosteum and marrow indirectly, and play a most important part in the result of a transplant. There are no Haversian canals in the outer layer, but here are found in the large channels Volkmann's canals. The interstitial or intermediate lamellæ occupy the spaces between the Haversian systems. They represent the remains of peripheral lamellæ. They are usually short, and very irregular, but possess lacunæ and canaliculi, and are arranged as in the Haversian system, and with which they connect.

The Haversian or concentric lamellæ are circular layers, arranged around a center space or canal, known as "a Haversian canal". There is no fixed number of these layers, there being usually from five to ten. The layers of each system are parallel to one another, but the layers of the different systems cross at various angles. Be-

tween these layers are small irregular spaces called lacunæ. These lacunæ are connected by small canals or canaliculi, and the lacunæ nearest the Haversian canal communicate therewith, by canaliculi; in other words, there is a perfect network of small and large lakes and canals in the shaft of long bones.

The Haversian canal contains blood-vessels and nerves; the vessels in the canals are covered with endosteal cells, and the canals themselves are lined with the same cells. The space thus formed is the lymph channel, and into these canals the canaliculi empty. Thus, an indirect connection in the periosteum and endosteum is formed. In each lacuna is a bone-cell, or osteoblast—*the important part of the bone-graft.*

The spaces between the Haversian systems are occupied by the interstitial lamellæ, which are short and very irregular, but possess lacunæ and canaliculi, which are arranged as in the Haversian system. The lamellæ that surround the marrow cavity are irregular, they also possess lacunæ and canaliculi and the all-important osteoblasts, which are just outside of the endosteum.

The osteoblasts are irregular, flattened, stellate masses of protoplasm, possessing a number of processes. The protoplasm is granular, and each cell contains a large and distinct nucleus. Osteoblasts are met with in greatest number in the deep layers of the periosteum, and in the endosteum. Cancellous bone is found in irregular and in flat bones, and it forms the bulk of the

Fig. 1.—Skiagraph beautifully illustrating the axillary artery and its branches; also showing an artery of considerable size penetrating the humerus near its head. Location indicated by star. (Kindness of the late *John B. Murphy.*)

extremities of the long bones. Its anastomosing spicula form a network for the marrow. It contains lacunæ, and canaliculi, and the spicula have a fibrillar structure. In the ends of the long bones the spicula are placed, as a rule, at right angles to the planes of articular surface (the line of greatest pressure). They are bound together by other spicula that correspond in direction to the planes of the articulation (the line of greatest tension). The nearer the marrow cavity, the heavier and stronger these spicula are.

The blood-vessels that supply the cancellous bone are fewer and larger than those that supply the compact bone. The supply for both is derived from the periosteum, whereas the marrow derives it principally from the nutrient artery. This artery enters through the nutrient foramen, usually located near the center of the shaft, which passes obliquely through to the medullary canal. There the artery gives off branches towards both extremities, thus forming capillary plexus in the marrow, and communicates with the periosteal vessels. The walls of the blood-vessels in bone are very thin, and the current very slow; the veins are given exit in three places: from the long bone, with the nutrient artery, and at the articulating extremities, and from the compact substance. The latter two do not accompany arteries, but immediately after emerging from the bone they have numerous valves. In the flat and cranial bone the veins are numerous and large. The nerve supply to bone is very complete. The nerves are freely distributed to

Fig. 2.—Skiagraph of elbow showing fracture of the internal and external condyles of humerus; with ordinary 6-penny finishing nail driven through each condyle into lower portion of humerus, holding condyles in position; also, brachial artery (injected with lead) with its many branches around elbow-joint. (*J. B. Murphy.*)

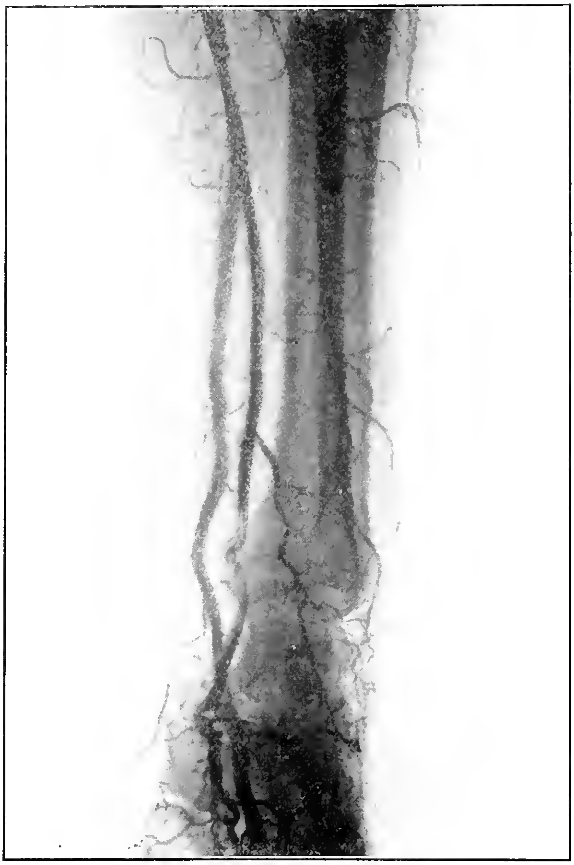


Fig. 3.—Illustrating circulation of forearm, wrist, and part of hand. (*J. B. Murphy.*)

Fig. 4.—Beautifully illustrating circulation of pelvis and hip. (*J. B. Murphy.*)

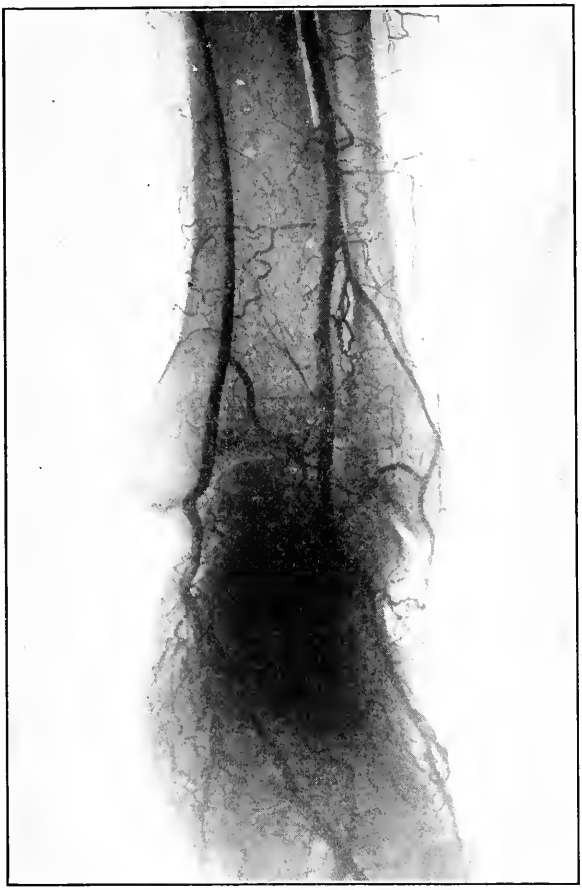


Fig. 5.—Posterior view of the lower portion of leg and foot. Also illustrating the posterior tibial and peroneal arteries, their position, and the branches given off from them.

the periosteum, and some of the fibers terminate in this structure as pacinian corpuscles. Nerves accompany the nutrient arteries into the interior of the bone, and also reach the marrow from the periosteum by way of Volkmann's and Haversian canals. They very thoroughly supply the coats of the arterials, and ramify about the osteoblasts. Articulating surfaces, as well as bone-tissue, are most completely supplied with nerves. In severe injury to bone or joint, great shock follows, on account of the destruction of nerve-tissue.

In studying the elements histologically of the periosteum, it must be studied in its proper relation to the compact bone, as well as when it is stripped from said member. Not only is it necessary to examine the periosteum intact, and that stripped from said member, but much depends upon the method used in separating it from the bone. If removed with a quick stroke of the periosteotome, and likewise a similar strip from the same location, but with a slow raising motion of the periosteotome, and each strip examined microscopically, the variation in the line of separation can easily be demonstrated. This variation becomes more marked when bones of different stages of development are studied.

The periosteum is a membranous coat of fibrous tissue. It consists of an outer layer, made up of interlacing bundles of dense fibrous tissue, and large blood-vessels, the branches of which penetrate into the underlying compact bone. Directly beneath this, and in contact with this outer-

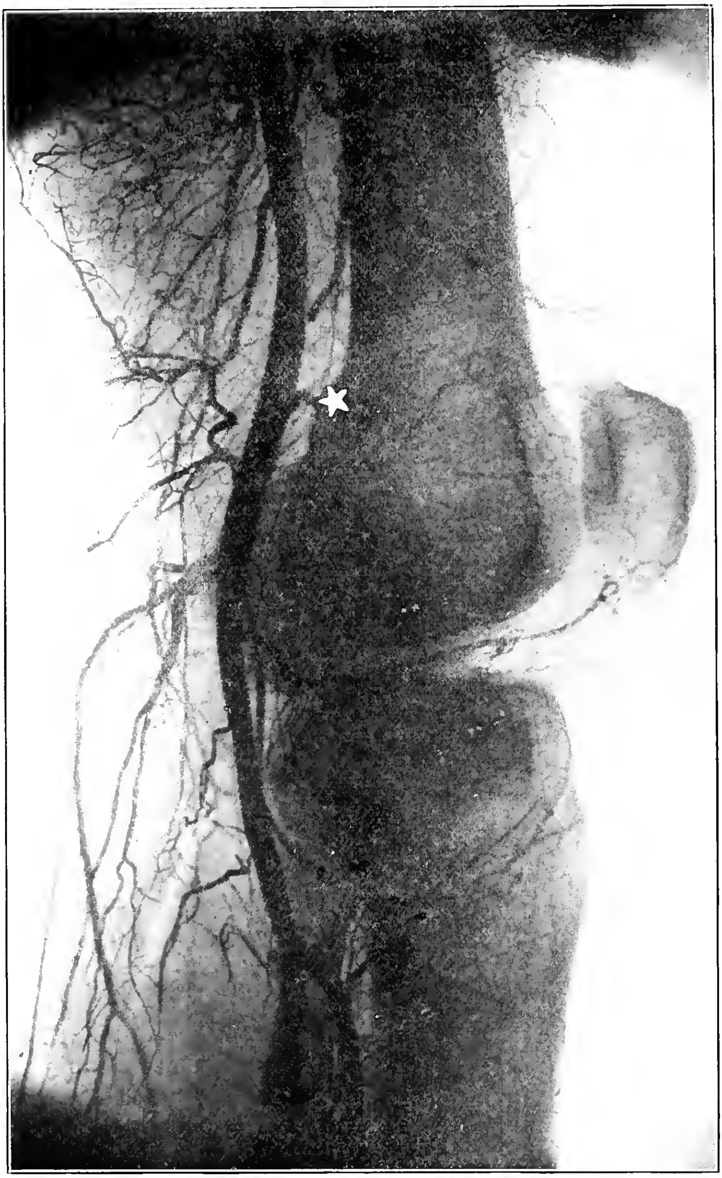


Fig. 6.—Skiagraph of the knee-joint showing the popliteal artery with its numerous branches. Star indicates a large artery entering the bone near the upper epiphyseal junction. (*J. B. Murphy.*)

most layer, is a firm fibro-elastic stratum, which varies with the age of the individual. In adult bone it is closely attached and firmly adherent to the surface of the bone; beneath this latter stratum there is a periosseous or cambium layer of tissue consisting of small vessels, numerous small cells, and fine connective tissue fibrils—the subperiosteal areolar tissue of Macewen.

The cellular elements are profuse in young or developing bone, and are easily divided into two distinct types—an outer layer of cells, with plate-like nuclei closely packed together, and an inner layer, consisting of small oval nuclei. These cells with plate-like nuclei are similar to those found in the perichondrium of true cartilage.

These two types of cells are probably dormant osteoblasts (Haas).

Microscopically, there is no demonstrable line of separation between the periosteum and compact bone.

The histological components of the stripped periosteum vary with the method of stripping, as previously stated, definitely proving that there is no distinct line of cleavage.

Again repeating, one specimen stripped slowly with a blunt instrument will contain cellular elements not present in a specimen stripped quickly, or with a sharp osteotome.

About 1740 Duhamel brought forth the first systematic work on the rôle that the periosteum plays in the repair of bone, and was the originator of the generally accepted modern theory.

It was his belief that the periosteum, intact, proliferated and became thickened about a fracture, and formed the callus by throwing out new tissue. He was also the first to define and use the term "cambium layer", of the periosteum, which, since the writing of Macewen, has become recognized as the all-important bone-growing element of that member, possessing as it does, when removed in a certain manner, a great many osteoblasts.

Over 120 years later appeared the great and important work of Ollier (1865), which has withstood the test of time, and remains today the principal foundation of all exact knowledge of the growth of bone. His work was so thorough that his conclusions have attained an almost unassailable position. He proved the regeneration of bone from periosteum intact, in every possible way, and ever since his day this membrane, in its normal position, has been regarded as one of the most important vital tissues of bone. Nearly half a century has elapsed since Ollier's treatise, and during this period practically the whole of modern surgery has arisen.

As previously stated, it is evident that the periosteum is a direct derivative of the chondroblasts; in the regeneration of bone the osteoblasts tend to revert to the chondroblastic type, which is shown by the formation of cartilage and bone at the same time in the early stages.

In the regeneration of cartilage there is a reversion of the chondroblasts to the connective-tissue type of the cells. After the periosteum has

proliferated into cartilage, it is rapidly transformed, either directly or indirectly, by some specific influence, perhaps of a chemical or physical nature, into bone. The cartilage, on the other hand, some of it, continues to grow as cartilage, but it also may later be changed into bone, as in old age. The growing and determining force is the same as that which is fundamental to all growing conditions, and is dependent upon a specific property of the cell, which determines the character of the tissue to be formed.

By carefully studying the voluminous literature, and reviewing the methods of experimentation, the question arises whether all the investigators have included or excluded the same components, and what constitutes the periosteum.

Are the constituent components of the periosteum constant, or are they subject to extensive variations, either numerically or in type and arrangement of cellular elements?

On account of the utter confusion which has arisen concerning the exact components of the periosteum, I shall give a concise description of its histological activity and change of same.

The histological structure of the periosteum differs in its component constituents at different stages of development of the body. During the stage of developing and growing bone the periosteum apparently contains an active third layer, or a periosseous layer, in which is found the fine connective-tissue fibrils, numerous small blood-vessels, and rows of small cells, the osteoblasts.

The term periosteum, as generally used, is understood to be the periosteum from a surgical standpoint. As such, it is considered as the membrane which remains after a careful subperiosteal resection of the underlying bone, special care being exercised that no bone elements are left behind. Moreover, it is definitely known that the periosteum, in different stages of bone development, contains special cellular elements in greater or lesser number. These cellular elements are also increased by toxic, chemical, or mechanical causes. Therefore, it will be expected that in experiments produced with such a varying structure as the periosteum, although all other details were identically carried out, the results would be at a greater or lesser variance with each other, even so far as absolutely contradictory results.

The gross anatomy of the periosteum is a dense fibrous tissue membrane, completely surrounding and adhering to the surface of the bone, except at the ends or articulating surfaces, where the bone is covered by cartilage. At the location of the tendon attachment, the periosteum becomes a part of structure. Many blood-vessels traverse the periosteum, and enter the compact bone through Volkmann's canals. When it is stripped from the living bone many bleeding-points are seen, which mark the site of the entrance of these blood-vessels.

Blood-vessels from the periosteum penetrate compact bone, and reach the marrow substance, communicating with branches from the nutrient

artery. The periosteum also furnishes the blood supplied to the cancellous bone, branches of which ramify in the cavities of the spongy part or parts of the bone.

After a thorough investigation, the author has come to the following conclusion:

1. That the periosteum in itself has no osteogenetic power, outside of the adhering osteoblasts.

2. By the removal of the periosteum from a bone-graft, a great number of osteoblasts on the surface of the bone are removed and destroyed, thereby reducing the osteogenetic function of the graft very greatly.

3. That if the periosteum is left intact on the transplant, it supplies nourishment by the blood supply to the osteoblasts that come in contact with, and just beneath, the periosteum, and cause them to live, thereby stimulating osteogenesis.

4. That the endosteum supplies nutrition to the osteoblasts on the inner surface of the bone, or that are nearby, or that come in contact with the endosteum, because of the thorough blood supply of the endosteum.

5. That if the endosteum is removed from the transplant, a number of osteoblasts on the inner surface of the bone are destroyed, with the blood supply, thereby reducing the osteogenetic function of the graft.

6. That by leaving intact both periosteum and endosteum we preserve the blood supply, thereby giving nutrition to the cells that are responsible for the regeneration of bone and nutrition which

is responsible for the apparent life of the graft or transplant.

7. Bony protuberances, condyles, etc., detached from all tissue save the periosteum, unite like free autogenous grafts covered with periosteum.

8. Detached bone, protuberances, or condyles, with healthy periosteal covering, and attached more or less to other tissues, continue to live.

9. By using autogenous bone-grafts, if good apposition is obtained, we have a very small callus, as small as in simple fractures, with good apposition.

10. The autogenous graft seems to live, but in reality it does not; the trabeculæ are gradually replaced by bone growing inward from the vascular spaces between them, while the cartilage continues to live, and to a limited extent aids in the formation of the new bone adjacent to it.

11. The principal replacement of bone in the trabeculæ takes place directly from the bone-cells, without the preliminary formation of cartilage; and the dead portion of the trabeculæ are absorbed in a line immediately adjacent to the new growing bone, without the addition of special cells.

CHAPTER III.

General Considerations.

FUNCTIONS OF THE PERIOSTEUM.

It is very evident that the periosteum has four distinct functions: (1), nutrition; (2), protection; (3), a limiting membrane; (4), that of strengthening and fortifying.

In an article in the "Journal of Surgery, Gynecology and Obstetrics," of May, 1913, Murphy stated: "The bone-graft, *per se,* does not possess any osteogenetic power, and merely serves as an osteogenetic purpose. The regenerative force is supplied by osteogenetic cells found normally in the Haversian canal and lacunæ of living bone."

One of the important recent contributions is that of Auxhausen (1898). It is readily seen that he assumes the position that neither bone alone, nor the periosteum, *per se,* is osteogenetic: some of the bone dies, but a portion of it retains its vitality; the periosteum and marrow substance remain alive, and produce new bone.

Macewen summarizes the function of the periosteum as follows: "The periosteum is of great use in limiting within specific boundaries the distribution of the osteoblasts, and preventing them, during the evolutionary period, from being scattered into soft tissues, where their presence would be prejudicial to the functions of these

parts. In the loose areolar tissue existing between the periosteum and the bone, the osteoblasts find nutriment for their growth, and space to regenerate."

Haas concluded "that the periosteum, especially in the presence of blood-clot, has the power to regenerate bone; that the regeneration of the bone never formed excepting when periosteum was present." In a recent article he stated "that it is apparent from his studies that periosteum is very actively concerned in the regeneration of bone. There is at first a proliferation of all its cellular elements to produce a cartilaginous material, which in turn is changed into bone."

Groves states "that every practical worker on the subject has endorsed the opinion that a living bone of the same species gives much quicker, stronger, and more certain results than dead bone, or than that taken from any other species."

John B. Murphy states that in order to achieve the best results in the work of bone-grafting and bone-transplantation we must observe or keep in mind the following rules:—

1. (*a*) "Normal periosteum completely detached from bone transplanted into a fat or muscle-tissue bed, in the same individual, if he be young, may produce a permanent bone deposit, but only if osteoblasts remain attached to the lower layer of the periosteum. The periosteum of itself, is not osteogenetic; it is rather a limiting membrane, and therefore it is of advantage to transplant it with the bone, although it is not essential in all

cases to do so. (*b*) Normal periosteum, transplanted into another individual or animal of the same species, and under the same condition, rarely, if ever, produces a permanent bone deposit. Any bone that is formed from such periosteum will, sooner or later, be absorbed. The osteogenetic effort of this periosteum is early exhausted. (*c*) Normal periosteum transplanted into another species never produces a permanent bone deposit.

2. Strips of normal periosteum raised from the bone detached at one end, but left attached to the bone at the other end, if turned out into the surrounding tissues, usually have bone produced on the under surface at the osteoperiosteal angle, but not unless there are osteoblasts attached to it. This is an etiologic factor of many of the exuberant calluses in fractures in the neighborhood of joints. The periosteum and some of the osteal cells are torn loose by the muscular contractions at the muscle attachments, or elevated by the fracture, and these develop traumatic exostoses.

3. Normal periosteum transplanted into other individuals or animals of the same species, and contacting at one end with exposed or freshened bone, rarely, if ever, produces permanent bone, even for a small extent, at its basal attachment, and never produces bone for its full length.

4. When bone with its attached periosteum is transplanted into muscles, fat or other soft tissues, in the same individual, and free from bony contact, it may for a very brief period of time

show osteogenetic powers, but eventually the formation of the new bone ceases, and all of the bone is absorbed, except in the cases of very young children or infants. When transplanted into another species it is always absorbed.

5. Free bone, from which the periosteum has been detached, when transplanted into muscle or other soft tissues, always dies, and is ultimately absorbed.

6. Bone, with or without periosteum, transplanted in the same individual, and contacting with other living osteogenetic bone at one or both ends, always becomes united to the living fragments, and acts as a scaffolding for the production of new bone of exactly the same size and shape as the original bone, provided the most perfect asepsis is maintained. This new bone subsequently increases to such a size as is necessary to give the support required by nature in the extremity in which it has been placed. It acts as a *scaffold* for the production of new bone, but allows the osteoblasts, which are normally found in the Haversian vessels, to travel into the Haversian canals of the transplant. When one end of such a transplanted piece of bone projects into a joint, and when it is surrounded by the original joint capsule, the normal conformation of the bone end in the joint is reproduced almost in its entirety, such as the head of the tuberosities of the humerus, and the upper extremities of the femur, including the trochanters, provided the muscle stumps are fixed to the transplant at the time of

operation, in about their normal anatomic relation with sutures.

7. The transplant, no matter how small or how large it may be, is always ultimately absorbed. It is my conviction that its rôle in the reproductive process is merely that of a mechanical support from the Haversian blood-vessels and the living osteogenetic cells as they advance from the living bones at both ends and pass through the Haversian canals, canaliculi, and lacunæ, of the transplant. New lamellæ are deposited around the new capillaries, and these lamellæ adjust themselves in the graft in such a manner that a firm bony union is formed, and the continuity of the bone into, or on to, which the transplant has been placed, is re-established, and to such a degree as to give sufficient support to the limb before the transplant is entirely replaced by new bone or the transplanted bone is absorbed.

FUNCTION OF THE TRANSPLANT.

We have had the opportunity of observing that ultimately all of the transplant disappears. As the new lamellæ are formed by the osteoblasts, the osteoclasts eventually dispose of the transplant, and this building up and tearing down process by the osteoblasts on the one hand and by the osteoclasts on the other, keeps pace. As rapidly as new bone is formed in and around the transplant, the old bone is absorbed.

"The graft, *per se,* does not possess any osteo-

genetic powers: it merely serves as an *osteo-genetic-conductive* purpose" (Murphy). The regenerative force is supplied by the osteogenetic cells found normally in the Haversian canals, and lacunæ of living bone. However, in order that this new formation of bone may be made possible, the transplant or graft of bone is an absolute necessity.

It is a well-known fact that unless the graft is firmly contacting with living bone the osteogenetic cells will not pass over from the living bone, or give stimulus to the transplant, and *vice versâ.* I have had one case in my clinical experience in which that was demonstrated. One end of the transplant only was firmly contacted with living bone, and here a firm solid bony union took place. The other end of the transplant had partly freed itself from its contact with the living bone, so that it was loose, and not firm; while there was some callus formation at this end of the transplant, there was no other effort at bone union.

8. I have found from extensive study of skiagrams of cases in which bone-transplantation has been done that the graft increases in size on the surface in the same manner as the deposits of bone lamellæ take place in the normal growth of bone; that is, by piling up of the deposits of bone; in layers beneath the newly formed periosteum. Any osteogenetic force which may be possessed by the periosteum is imparted to the periosteum by such osteogenetic cells as may be attached to its under surface.

9. When bone is transplanted to supply a defect in that portion of bone which enters into the formation of a joint, such as the upper end of the humerus, or the upper end of the femur, the muscles in the vicinity of that joint should be fixed to the transplant, or firmly sutured around the transplant, in the same relation as exists normally, if muscular control and muscular fixation of both has taken place. The musculotendinous attachments of the muscles should be sutured accurately around the graft at the point of desired union.

10. Bone covered at the end by cartilage and at the sides by periosteum, such as the phalangeal bones, even when contacting with living bone, dies, and is entirely absorbed. The interposition of any tissue, either cartilage or periosteum, between the surface of living bone will effectually prevent the passage of the Haversian vessels and the osteogenetic cells from one bone into the other, and failure of union is inevitable. That is a positive law. Regeneration can take place only when living bone contacts with living bone, without any interposing substance, so that the osteogenetic cells may find their way out from the bone into the transplant.

The essential feature to be borne in mind in carrying out this work is, that the transplant must contact with living bone, at at least one end. If the epiphysis of the long bone has been destroyed, the bone will not grow in length from the trans-

plant, at the point of epiphyseal absence, unless an epiphysis is transplanted thereto.

If the entire shaft of the long bone, such as the tibia, humerus, radius, or ulna be absent, then the bone must contact with the neighboring bone, laterally, or at one end or the other of the extremity across the normal line of the joint, in order to get an osteogenetic supply, as in the case of absence of the tibia the graft articulates with the neck of the femur, or astragalus. Subsequently an arthroplasty can be done to give the patient a movable joint.

The indications for bone transplantation are as follows:

1. To correct the deformities resulting from defective development, such as aplasia of the bones of the extremities of the nasal bones, and of the mandible.

2. To effect union in ununited fractures, no matter how remote the occurrence of the fracture, no matter whether of congenital or purely traumatic origin.

3. To restore or supplant such parts of the bone as may have been dislodged or destroyed by fractures, as in the case of fracture through the head of the anatomic neck of the humerus or femur, etc.

4. To replace bone which has been removed because of its having been the seat of non-malignant neoplasm, such as a cyst, a myeloma. or osteitis fibrose cystic, etc.

5. To replace bone which was removed because

of having been the seat of encapsulated malignant disease, such as chondrosarcoma, or fibrosarcoma.

6. To replace bone which has been destroyed by an infection, such as osteomyelitis, tuberculosis, etc.

Dr. Albee states that he has repeatedly and successfully used bone-grafts for spanning through tuberculosis of the ankle and knee-joints; that the cortical bone-graft has always withstood pure tuberculous infection, providing it has satisfactory connections with healthy bone on each side of the infected focus; that it will also resist attenuated pyogenic infection under similar conditions has been proved by experiments conducted by Phemister and others, in both surgical and laboratory work. The importance of this inherent germ-resisting property of the bone-graft is readily apparent, in that it doubly assures its trustworthiness as a general surgical agent (when compared with metal). Especially is this true in the application to compound fractures in which infection is feared, or where mild infection has already occurred.

CHAPTER IV.

THE REPAIR OF BONE.

A WOUND to bone is caused either by transverse or by longitudinal stresses producing fractures or fissures of bone-tissue, or in perforating wound, produced by bullets or sharp missiles. The injury is not confined to the bone structure alone. The periosteum is usually torn across, or raised from the shaft of the bone by a separation of the fragments and the connecting muscles, and vascular tissues immediately surrounding the site of the injury are damaged. Only in simple and fissured fractures, without displacements of fragments, are the injuries to the surrounding tissues kept within moderate bounds. The amount of the blood that exudes into the surrounding structure depends upon two things: (1) the density of the tissue, and (2) the size of the blood-vessels injured.

If the infiltrate of a considerable amount of sanguineous fluid appears some distance from the point of fracture, we know that a vessel of considerable size has been injured. The amount of blood, however, which escapes, as a rule, is slight, and confines itself chiefly to the medullary canal. The discoloration of the skin is due to laceration of the capillaries received during the accident. The destruction of tissue in compound fractures is

much greater, and the amount of blood set free is naturally more abundant. Reparative changes commence about the seat of fracture a short time after the injury is produced. Complete restoration of the structure may ensue, and after a few months scarcely a trace of the injury be obtained.

The reparation or healing of fractures is not a growth of bone-cells, but a production and organization of new tissue, which surrounds the injured parts or fragments, and is derived chiefly from the periosteal covering of the bone.

I will consider the process in two stages: (1) the formation of a callus, that which completes the union of the parts; and (2) the absorption of the redundant portions of the callus; and the ossification is completed by the deposition of lime in the newly formed tissue. However, strictly speaking, both of these processes in some degree go on simultaneously. Within a week or ten days after the occurrence of the fracture, calcium salts are deposited in the newly formed osteoid and cartilaginous tissue. As previously stated, the periosteum and endosteum play a very active part in the formation of the callus, which unites or cements the ends of the bone. The callus produced from the periosteum is termed the "periosteal callus"; that from the endosteum, the "myelogenous callus", while the new tissue which lies between the ends of the fragments is commonly designated the "intramedullary callus".

In early childhood the cartilage which exists at the epiphyseal junction is capable of forming

callus. A large callus is formed in fractures of the shaft of the long bone; a much smaller growth is usually seen in connection with fractures at the epiphyseal ends of long bones, in fractures of the body of the vertebræ, and in flat bones of the pelvis and skull. The amount of callus formed is very valuable, and partly depends upon the condition and size of the bone fractured, and the form of the injury. For instance, in fractures of the skull, the external callus can scarcely be designated by a palpation; however, when the displacement of the fragment is considerable, a very large callus is formed.

Clinically, the regeneration of bone is an extremely important matter, and it is well to appreciate that the regeneration of bone, like the regeneration of cartilage, is merely the regeneration of a somewhat modified connective tissue, as previously stated. The new cells in each are, in the earliest stages, exactly like the fibroblasts. This is not remarkable when we remember the relationship between the three tissues; cartilage becomes converted into bone; the periosteum may give rise to fibrous tissues, as happens when a fibrous union occurs instead of an osseous. Further, although we are accustomed to speaking of bone arising with or without the previous interposition of cartilage, both kinds of bone are actually modified connective tissues, and no distinction is to be made in their form of regeneration. Regeneration of the medulla is of the same order as that of the periosteum. The long bones

have remarkable qualities of regeneration. In the lamellæ of the bone itself, as well as in the periosteum and the medulla, there is constantly regenerative changes going on, and old bone is being replaced by new. The periosteum and endosteum play their part in these changes; in fact, all these forces which build up the bone in the first place take part in regeneration and repair after injury or destruction.

Murphy states that the amount of growth in a bone depends on the need of it.

According to Wolff's law, "every change in the form and position of the bones or of their function is followed by certain definite changes in their internal architecture, and by equally definite secondary alterations of their external conformation, in accordance with their mechanical laws".

"The keynote of all bone development seems to be a co-ordinate arrangement of the bone-cells in lateral and end-on relations to each other, under the stimulus of pressure and strain within certain limits of intimate capacity" (Bond).

CHAPTER V.

Repair of Bone in Detail.

The softening and swelling of the periosteum is the first evidence of the inflammatory reaction, or the first step of repair; here we notice leucocyte migration from the vessels, the endothelium of which is markedly swollen. Proliferation of the connective tissue cells begins within twenty-four hours. A soft tissue thus produced by the inner layer of the periosteum consists at first merely of a very vascular connective tissue, containing numerous spindle or irregular-shaped cells, termed osteoblasts, which lie in a stroma which is partly hyaline and partly fibrous tissue. A change takes place four or five days after the fracture in the fibrous tissue, resulting in the formation of small masses or clumps of a substance resembling bone, but not containing calcium salts—osseous tissue. This osseous tissue, as it is called, is ultimately changed into bone. Any excesses remaining are finally removed by the osteoclasts. The connective tissues in the meshes or interstices become altered by a marrow-like substance. The hyaline areas referred to above develop into the so-called chondroid tissue, or into true cartilage. The amount of cartilage which is formed in fractures is largely governed by the displacement; where apposition is perfect, we find very little. When marked deformity is present (Fig. 7) a greater amount of car-

Fig. 7.—Skiagraph of the arm showing a vicious fracture of humerus near the junction of middle with the lower third. Six months after accident. Fairly good union, notwithstanding the overlapping of the bones and deformity existing.

tilage is formed, and this cartilaginous part of the callus is of the greatest importance in the final construction of bone, which cements the fragments. Again, the greater portion of the cartilage is produced by the inner layer of the periosteum. After the cartilage has become thoroughly vascularized, ossification takes place by direct transformation.

Should the ends of the bone be separated by too great an interval to permit of suitable callus formation, or should muscle or tendon be forced between the ends of the fractured bone, or if proper immobilization of the fragments has not been obtained, union may not take place at all, or there may be a fibrous union.

Complicated fractures, such as compound-comminuted, heal in a manner similar to those of simple variety, providing infection does not occur. Should infection occur, we will have a delayed or very imperfect union, which is caused either by thromboses of the vessels or death of the periosteum, and necroses of the bone may follow. The overabundant granulation tissue which follows such condition, is liable to interfere with proper callus formation. Finally, the callus that is produced is more abundant than is necessary for the proper union of the fractured bone. Considerable time after the repair has begun, the partial ossification of the callus has occurred; the redundant external and internal callus begins to be absorbed. It is generally believed that the absorption is accomplished by large multinuclear cells, known as osteoclasts.

Some observers are inclined to regard the osteoclasts as of minor importance in the shrinking, and consider the regressive changes in the callus as a type of diseased atrophy, or resorption, due to general ferment of the tissue, thus restoring the bone to practically the original condition, with possibly the following exception: a slight narrowing of the medullary canal, and a hardly perceptible thickening of the shaft; the redundant fibrous callus is also reduced in volume by granular contraction of its elements, and a shrinkage of its blood supply.

CHAPTER VI.

The Evolution that has Taken Place in the Treatment of Fractures.

Great advancements have been made in the treatment of fractures of every description within the last ten years, and much credit should be given Mr. Lane for the progress of asepsis and the most perfect operative technic he has developed. Much has been accomplished in bone surgery since Mr. Lane's initiative work, that hitherto seemed hopeless. Within the last few years surgeons have been considered radical who have intervened surgically in the treatment of simple fractures. On the other hand, I have known surgeons with little judgment or surgical skill, who have attempted the operative treatment of fractures, and, aside from frequently infecting the wound, by faulty technic, have often added foreign materials, which might have caused suppuration later.

Reduction of fractures by manipulation (closed reduction) is not without danger to vessels, nerves, and muscles, and in many cases does not attain the desired end; *i.e.*, the return to proper alignment, or normal anatomical relations. For example, take the usual fractures of the femoral shaft, in which the end-to-end apposition is rarely obtained. However, this is only one of many, out

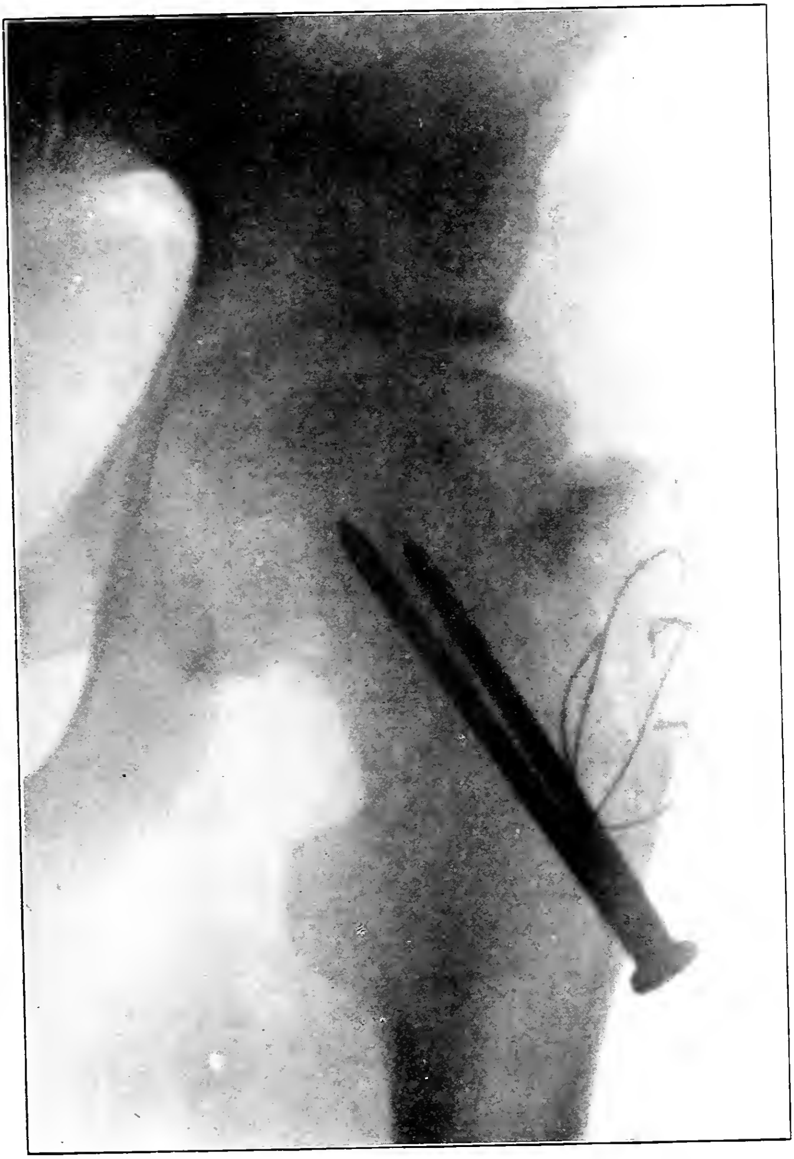


Fig. 8.—Fractured neck of femur. Two 12-penny nails are seen driven through upper end of femur, through neck, into head of bone; also broken wire used in fastening fragments together. (*J. B. Murphy.*)

Fig. 9.—Fracture of lower end of humerus near elbow-joint, showing considerable deformity. Skiagraph taken six months after accident. Position of fragments interferes materially with motion of elbow-joint.

Fig. 10.—Oblique fracture of the femur near junction of the middle with upper third. This form of fracture is very hard to hold in position, and, as a rule, good results do not follow the external method of treatment.

Fig. 11.—Fracture of the humerus near juncture of middle of lower third, of six months' standing. Bad deformity, with attempt at bony union.

of a large proportion of fractures; there is a certain percentage that have given unsatisfactory results following the closed method. Then such group, I believe, should be subjected to the open method, and to anatomical reduction of the fragments. Aside from the return to the proper alignment, there should always be considered the question of joint strain, as is strikingly seen in special work more than in general surgery.

The general surgeon treats his common fractures of the femur in the usual way (closed method), and gets union, and often never sees the patient again after bony union takes place. Years after, the orthopedist is consulted, and finds that the patient is suffering with scoliosis, resulting from a short leg, following an ill-treated fracture.

In a young, growing child, a shortening of three-quarters to an inch will cause joint-strain, which results in the development of structural deformity. Nevertheless, the general surgeon considers half- or three-quarters of an inch shortening a good result.

CHAPTER VII.

Operative Treatment of Fractures.

FACTORS TO BE ACCOMPLISHED.

The day is near at hand, when all fractures of the femur will be subjected to the open method (excepting those occurring in infancy), for in the open treatment the alignment is perfect, and we do not have any shortening, providing the work is done correctly. Up to the time Mr. Lane began insistently to champion the open method, also the use of metallic plates, strong prejudice against the open treatment existed. This was created partly by the results obtained, and partly by tradition. Immediately non-traumatic and strict aseptic surgery became recognized as all-important.

At present, the opinion of the up-to-date surgeons who are doing bone work is a unit in regard to the question of the open treatment of simple fractures. The open treatment of fractures of the patella (Fig. 12) has been practised for years; gradually this effort to secure not only bone union, but actual approximation of the fragments, has been accomplished. These attempts were carried to fractures of the olecranon process (Fig. 13). Since the perfection of bone surgery technic the field has been so enlarged as to include every one of the long bones of the body, in

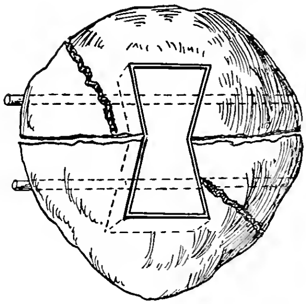


Fig. 12.—Outlining bone-inlay used to hold fragments together in fracture of patella. Also shows bone-pegs in position, giving firmness and rigidity to the transplant.

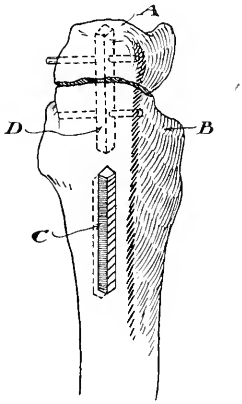


Fig. 13.—Illustrates the author's method of removing the rectangular dowel from the distal fragment in fracture of the olecranon process, driving it into a "tunnel" made in end of fragment *A* and extending into fragment *B;* driving graft *C* into position, as shown by dotted lines *D.* Fastened into position by bone-pegs.

which reduction is either difficult or impossible, or in which the fragments cannot be kept in position by the ordinary methods.

It matters not what mode of internal fixation is used, whether the intramedullary dowel or inlay graft, the limb should be firmly immobilized with plaster-of-Paris cast or splints in as nearly a neutral position as possible. The position in which the limb should be placed will cause the relaxation of the muscles, which have a displacing influence in said fracture. If the above is closely observed and followed out, the intramedullary dowel, inlay graft, or neck of femur spike, will not bend or break during the period of postoperative fixation. In all cases of persistent non-union, whatever the contributing cause may be, whether syphilis or any other systemic condition, with hidden influences producing meager callus formation, such conditions should be treated before operative procedures are undertaken.

Any operation for the reduction of simple fracture, and followed in the majority of cases by an intramedullary dowel or inlay, is a step which should be only undertaken if the surroundings and facilities for an aseptic technic are perfect, or nearly so, and the surgeon is equipped with proper instruments.

Such conditions can only be found in modern hospitals. An attempt to perform such operation without the proper equipment, surroundings, and precautions, means infection, which, although it may not prove fatal, will jeopardize the usefulness of the limb.

Fig. 14.—Pott's fracture with internal malleolus broken off; also, fracture of fibula about two inches above joint. Ordinary 10-penny nail driven through internal malleolus into the tibia, and two 8-penny nails driven through fibula into tibia. (*J. B. Murphy.*)

With aseptic surroundings and the proper equipment, in experienced hands, danger of infection is no greater in bone work than it would be in any other major surgical operation.

The extensive and accurate use of the X-ray has undoubtedly played an important part in the development of the tendency to open up simple as well as complicated fractures.

Those who have had occasion to treat a great number of fractures, and have had the privilege of subjecting them to X-ray examinations have found that the radiograph will often show a marked displacement of the fragments; so great, in fact, that one would expect much visible and palpable displacement or deformity, but by examination in the ordinary method we are often deceived. Hence the X-ray is indispensable to the surgeon who wishes to get the best possible results, and who wishes to be honest with his patients and himself as to the real condition existing.

The advent of open treatment has, however, brought many disastrous results, first, by bad technic; second, by introducing foreign material; but with perfect asepsis, and equal technic, we can safely expose the ends of the fractured bones, and skillfully adjust them, with less danger to the surrounding parts, than by reducing them by the closed method. A surgeon thus well-founded has the moral right to treat any fracture by the open method, and does not thereby add to, but deducts from, the existing danger. This undoubtedly is the greatest advance that has ever been made since the advent of bone-plating.

CHAPTER VIII.

The Use of Foreign Material.

The application of a metallic plate to broken bone requires a special technic; infection has occurred in a varying percentage of cases, with serious inhibitory effects. The metallic plate or any foreign body, placed over the fractured ends of a bone, prevents the formation of callus over such area, also invites infection. Is it any wonder that such a great number of failures have followed?

Foreign bodies such as nails, screws, and wire are tolerated in the human body with surprisingly little reaction; they remain firm for a while, providing the technic is perfect during application, but sooner or later we have rarefaction and absorption of the bone that comes in contact with said foreign material, with mild infection following, which may result in caries or necrosis.

Martin states: "It is noteworthy that union is usually delayed by the Lane plate; that the time of treatment repair as a rule, is not shortened; that the results are not uniformly good, but, taken as a whole, they are infinitely better than could have been secured by other than operative means. There seems to be a relation between the size of the internal (metal) splint and the promptness of final union. In other words, we have felt that the less foreign matter we have put into the wound,

Fig. 15.—Fracture of upper third of humerus just above insertion of deltoid muscle. Skiagraph shows Lane plate, which was applied six months before taking of picture. No union between ends of fractured bone.

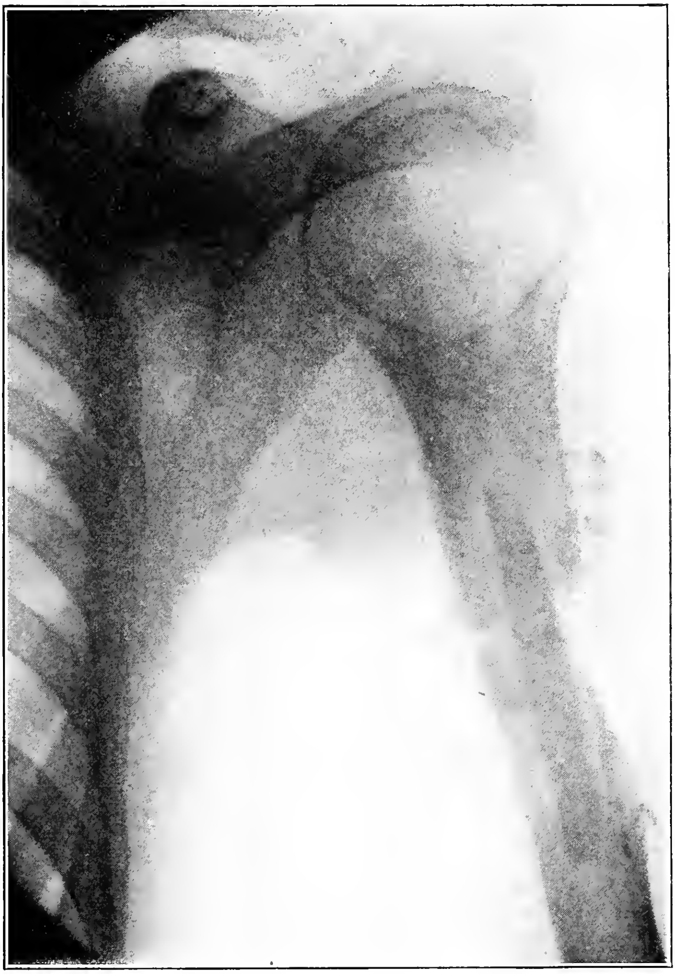


Fig. 16.—Same as Fig. 15. Lane plate has been removed, and intramedullary dowel applied. A perfect result followed.

the quicker it gets well." *It is a fact* that any *foreign material* (Fig. 17), (metal plates, ivory or iron pegs, silver or copper wire, etc.), in contact with bone will eventually set up an irritation which is followed by a rarefaction and absorption of the bone; and in some cases, osteomyelitis, caries or necrosis follows. We notice in some cases (as seen in Fig. 18*A*) all screws are loosened, and the presence of the plate has caused considerable absorption of both ends of the bone by its contact. This is a common occurrence; and in a very large percentage, where the Lane plate has been applied, removal is necessary, not at any particular time, for years may elapse before any disturbance occurs. Then the patient is forced to seek relief, and the consulted surgeon finds that he is compelled to remove the plate or foreign material (Fig. 18*A*) with one or more of the above changes present. Also in old cases of excision of the knee-joint, in which silver or copper wire has been used, discharging sinuses have opened ten or fifteen years after the insertion of the wire.

There is no question but that the presence of a metallic plate, instead of stimulating osteogenesis, retards it; therefore autogenous bone-grafts with periosteum are in great favor, for not only do they produce bone themselves, but they stimulate the bone ends, with which they come in contact, to a more active osteogenesis. There forms an immediate adhesion between the graft and the fractured ends, and as time elapses it becomes

Fig. 17.—Same as Fig. 14. Side view of Pott's fracture in a young lady 18 years of age, showing three nails in position. One 10-penny ordinary spike driven through the internal malleolus up into tibia, and two ordinary 8-penny nails driven through lower fragment of fibula into tibia. (*J. B. Murphy.*)

firmer and firmer united, until we have a perfect bone-union. And furthermore, unlike a foreign material, the graft has certain bacteria-resisting properties.

Fig. 18.—*A*, fracture of both bones of forearm. Skiagraph shows Lane plate, applied five months previously, no union. Plate was removed and intramedullary dowel applied. *B*, six months after intramedullary dowel was applied. Perfect result.

"I have always believed that the less non-absorbable foreign material used the better, and my next preference to nothing is chromicized gut;

and I prefer a single screw to a plate and eight screws" (Williams). Even as the indications for operation vary, so do those for the internal fixation. The amount of internal fixation depends upon whether it is necessary to steady the fragments until the external fixation is applied, or whether it is to be subjected to violent strains, as may happen for instance in some fractures of the femur. It has been amply proven by experimental and clinical evidence that a constant strain will loosen the strongest form of internal fixation; just as a suture drawn too tight will produce absorption and cut through the soft parts, so will a constant strain draw or loosen the screws of a plate, no matter how well introduced. The point I wish to make is, that we have to rely chiefly upon the external dressings, the function of the internal fixation being to obviate positions or displacements which may be caused by muscular action or by sudden strain, such as may happen during the application or change of external splints or dressings. "One of the chief advantages of internal fixation by autogenous bone-graft is the possible early and passive motion of neighboring joints without endangering union" (Blake).

Therefore all foreign material should be condemned, and their use be discontinued.

CHAPTER IX.

Technic of Transplanting Bone.

In order to be successful in this branch of surgery one must have a very complete knowledge and a clear conception of embryology, histology, anatomy of the bones and joints, as well as the form or type of regeneration, not only in bone, but also in soft tissues. No matter how this work is done, or what theory is used, it must be carried out along definite lines, as closely as possible. It may be said with positiveness that the question of what sort of material, and from what source it should be taken, in the osteoplastic work has been solved.

While the implantation of homogeneous material derived from a subject of the same species may be useful in a limited number of cases, as a mechanical support, it is not all a matter of repairing a defect, but of supplying the proper means which will favor the reproduction of the tissues to fill in or correct the defect. This is a well-known fact to those who do osteoplastic work. We cannot repair a defect in bone, but we can resort to procedures which will stimulate the regeneration of the bone already present, or remaining, thereby filling in the defect by the reproduction of tissue (Fig. 18).

All fractures should be treated by operative interference where the following conditions exist:

1. Where there is considerable displacement of fragments that cannot be otherwise reduced, or there is difficulty of maintaining them in apposition.

2. Where reduction cannot be completely made by manipulation.

3. Where there is interposition of a spicula of loose bone, or soft tissue.

4. Where fragments are rotated upon each other and cannot be reduced and held in position by the external method.

5. Where the fracture is a spiral one; also in multiple fractures, etc., etc.

Special indications are, in fractures where we have pressure upon the blood-vessels or nerves. Also fracture of the clavicle if the patient is a lady, and wishes to appear in evening gowns, perfect apposition is necessary, so that the slightest deformity will not appear.

In fractures of the upper end of the humerus, when complicated by dislocation, in fracture of the shaft of the humerus, where there is involvement of the musculo-spiral nerve, in fracture of the neck of the femur, it is always indicated, and in the majority of cases of fractures of the shaft of the femur, as it is difficult in most cases to secure good apposition by the ordinary method. Statistics show that the operative treatment has been more frequently employed in connection with fractures of the leg than any other part of the body.

Fractures in close apposition to the joints, as well as epiphyseal separation, with displacements,

demand operative interference. Fragments displaced in the elbow-joint (Fig. 19) or any other joint, are apt to be followed by serious interference with the function of the joint, if not treated by the internal fixation method.

Then it is the *duty* of the surgeon, knowing the danger menacing the patient in such cases, to proceed at once by operative measures to correct such conditions.

The operative technic for articular fractures is very difficult, and the operation should not be undertaken by a surgeon unless he has had considerable experience in bone-work.

The advantages of an open reduction in simple fractures are: (1) that the patient is able to resume his occupation at an earlier date; (2) that the large blood-vessels can be tied, if necessary; (3) that the pressure on the blood-vessels and nerves can be relieved; (4) that anatomical accurate apposition can be secured and maintained; (5) interposed parts, like fragments of bone, nerve, muscle, and periosteum, can be removed; (6) in fractures that are close to joints there is less danger of ankylosis; (7) in T-fractures of the elbow, and in fractures of the patella, olecranon, and os calcis, a firmer union can be secured, etc., etc.

Hitzrot has well said that "the most striking counterindications for operations on broken bones are: INEXPERIENCE on the part of the surgeon, UNSUITABLE SURROUNDINGS and INSUFFICIENT EQUIPMENT." Furthermore, the

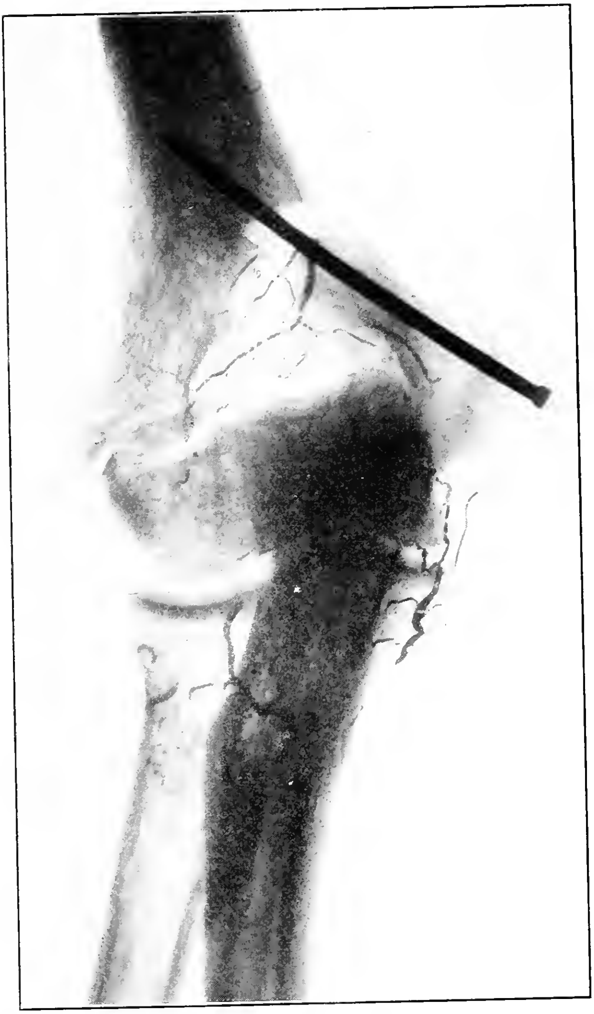


Fig. 19.—Fracture of lower portion of humerus extending into joint. A 10-penny finishing nail has been driven through internal condyle and lower fragment into shaft of humerus. (*J. B. Murphy.*)

operator, to be successful, must have a thorough knowledge of the region to be operated upon, and should understand the action and function of the muscles, ligaments, etc., involved in the injured member.

Such knowledge may prevent some of the most noticeable failures brought about in the treatment of broken bones.

CAUTION AGAINST THE TOO ENTHUSIASTIC ADOPTION of the open method in the treatment of fractures, as a routine means of dealing with simple fractures, SHOULD BE GIVEN WITH EMPHASIS.

Excellent results can often be secured, both as to anatomical restoration and function, by non-operative treatment, by a surgeon of experience, and who has a mechanical mind, and who has acquired the knowledge of the management of the application of plaster-of-Paris, and the use of the various splints.

There is no question in the author's mind but that the promiscuous internal use of the Lane plate has done much to prejudice the mind of the public as well as the physicians against the open treatment of fractures; for without the Lane technic, which few possess, the application of a metallic plate or any foreign body to or within the bone invites infection and delays union or causes non-union. Both of these results, especially the latter, and to a very large degree the former, can be overcome by the use of the autogenous intramedullary dowel, or the inlay bone transplant.

The author wishes to emphasize again that the presence of the metallic plate, instead of stimulating osteogenesis, retards it. This is in striking contrast to the autogenous bone-graft, which not only produces bone itself, but also stimulates the bone ends to a more active reparation. If properly applied, an immediate adhesion of the intramedullary dowel or inlay to the walls and the ends of the fractured bone occurs, and, as time elapses, it becomes a firmer and firmer bony union. Not only does the graft have the above qualities, but it also has certain bacteria-resisting and bactericidal properties.

It might be well to mention again a few of the fractures that are most liable to require the open treatment; namely, the long bones, especially the femur; fractures involving the joints, as fractures of the neck and the lower end of the femur; the upper end of the humerus; fractures of the lower third of the tibia, and fractures of the forearm.

Hitzrot enumerated the following indications for open treatment: Fractures of the head of the radius, with displacements of the fragments, or where the fracture line involves the radio-ulnar joints; fracture of the olecranon, with separation of the fragments; fractures of the head of the radius, with displacement; fracture of the patella, with separation of the fragments; fracture of the shaft of the long bones, in which the soft parts become interposed between the fractured ends of the bone; fractures of the tarsal and carpal bones, with wide separation of the fragments, or displacements of the fragments; fracture dislocation,

viz., fracture of the neck of the humerus, with dislocation of the head of the humerus, and where the tuberosities and condyles of the various bones are fractured, with rotation of the fractured processes; for example, fracture of the external condyle of the humerus, with rotation of the condyle, so that the fractured surface points outward, or away from the line of fracture of the shaft.

Especially is the open treatment indicated where we have hemorrhage, due to injury to a large vessel, when there are signs of compression of the nerves, and when the sharp point of a fragment is caught in the skin, and also when infection has occurred in the region of the fracture.

Most every type of fracture needs operative interference, if reduction is otherwise unfeasible. The necessity, then, for open treatment should be recognized at once.

The X-ray, as formerly stated, will aid materially in determining this fact, by looking at the fracture from several different angles.

The open treatment should not be regarded as a method only to be employed when non-operative methods have failed, as the results of secondary operations compare very unfavorably with those of immediate operation. As previously stated, skill, perfect technic, and surgical judgment are the most important requisites in the operative treatment of fractures, as a considerable proportion of failures is due to infection and poor judgment as to the time for operative interference.

I wish to emphasize that, in order to secure

the most satisfactory results from the open treatment, it should be resorted to as soon as the patient can be placed in favorable conditions and surroundings, and not defer operative procedures for ten days or two weeks, as suggested by some authors.

The British Medical Association appointed a committee, February 19, 1911, "to report on the ultimate results obtained in the treatment of simple fractures, with and without operations".

The committee reported as follows:

"It is possible by either non-operative or operative treatment to obtain a high percentage of good results in children. The results of non-operative treatment in children, with the exception of both bones of the forearm, are unlikely to be improved upon by any other method. Operative results expressed in percentage are approximately the same as the non-operative—1017 non-operative cases, 90.5 per cent. good functional results; 64 operative cases, 93.6 per cent. good functional results.

"In comparison with the results in children, the non-operative results in those past 15 are not satisfactory; and from the analysis of the age groups it is clear that there is a progressive depreciation of the functional results as the age advances in those cases submitted to non-operative treatment, *i.e.*, the older the patient, the poorer the result.

"Although the functional results may be good, with an indifferent anatomic one, the most certain

way to obtain a good functional result is to secure a good anatomic one. The operative methods which secure perfect apposition and absolute fixation of the fragments yield better results than methods which fall short of this; and imperfect fixation of the fragments by wire or other suture has been found unsatisfactory in fractures of the long bones (olecranon excepted). Operative cases in nearly all ages show a higher percentage of good results than non-operative cases. The mortality due to the operative treatment is so small that it cannot be urged as a sufficient reason against this method of treatment" (Hitzrot).

If the inlay method is used in fresh fractures, the bone being normal, the material for inlay grafts can be taken from the fragments themselves, and used as a stay and bridge across the fractured ends of the bone. Here, as well as in other similar cases, this work would be tedious and unscientific without the motor saw.

CHAPTER X.

Instruments and Their Use.

With the *Geiger* motor bone instruments one can saw bone, drill it, turn it into nails, or mould it into any shape or form required, with accuracy and speed; so that the surgeon himself can develop the delicate bone-work that is necessary in any case, with the least possible amount of time and trauma.

The electric saw has been a great factor in opening up the field of osteoplasty, and the application of bone-graft in various forms, that would have been almost impossible without this ingenious device. Since the advent of the motor saw it would seem barbarous for the surgeon to attempt to remove any size graft from one part of the living body to another with chisel and hammer. All cutting of bone that was formerly laborious is now done by means of electric power, and with accuracy and speed. The surgeon can do, and does, many things with motor instruments which would be almost impossible with hand instruments.

In November of 1912 the author visited New York, and while in one of the large clinics witnessed the removal of a graft from the tibia eight inches in length, which was placed in the arm and attached to the epiphyseal end of the humerus at the shoulder-joint, and to the remaining por-

tion of the shaft of the humerus, near the elbow-joint, the greater part of the shaft of the humerus having been removed five years previous, on account of the patient having osteosarcoma of the shaft of the humerus. It took the surgeon three hours and thirty minutes to remove the graft from the tibia of the patient, and place it in position in the arm. The removal of the graft was accomplished by the crude method of hammer and chisel. This unscientific and tedious method of

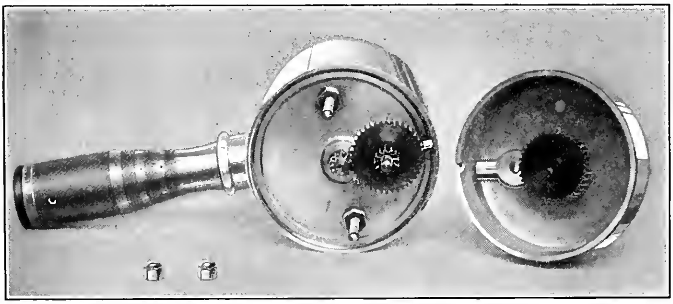


Fig. 20.—Showing reduction gear in author's motor, which reduces the speed from 7000 to 400 r. p. m. The cutters only run 400.

removing bone grafts so impressed the author that on his arrival home he proceeded at once to work out a more modern idea and technic of doing bone-work. The author conceived the idea of devising an electric motor, with reduced speed, after having thoroughly tried out the high speed motor, and found it not practical, as it burns the bone from which the graft is removed, and also the graft, thereby rendering it undesirable for grafting purposes.

The reduced speed idea was perfected, and the first motor that was completed was tried out by the late John B. Murphy, November 13, 1913, before the Clinical Congress of the Surgeons of

Fig. 21.—Illustrating position in which the late John B. Murphy held author's motor while doing bone-work.

North America, at Mercy Hospital, Chicago. After a thorough test, Dr. Murphy pronounced it a complete success. Dr. Murphy, who aided materially in the development of bone surgery, de-

voted a page and a half in his "Clinics" to this set of motor instruments in the February, 1914, issue, displaying a cut of the motor and cutters that were developed up to that time.

Fig. 22.—Skiagraph showing an oblique fracture of the tibia and fibula, with a square autogenous intramedullary dowel in position. When correctly applied gives perfect fixation and good results.

Considerable improvement has been made on motor, cutters, and accessories since Dr. Murphy placed his signature of approval thereon. After

the late Dr. Murphy demonstrated and approved the usefulness of the motor-driven instruments, November 13, 1913, several different designs of motor devices have been placed on the market. The work that is now being done in bone surgery is quite extensive, *i.e.*, dowel and inlay grafts, tongued and grooved, dove-tailed mortises and joints, etc., which could not be successfully done without the motor-driven instruments.

The difficulty in early days in getting out bone-grafts, and the results following the open method, then accomplished with hand instruments, caused prejudice and scepticism to prevail, and failure to recognize the real value of the transplant did undoubtedly delay the development of this most valuable surgical agent in this branch of surgery. The main reason that bone surgery did not develop along with the surgery of the soft parts was on account of the surgeon being unable to procure the proper instruments, until within the last four years, from which time bone surgery has made rapid strides.

In surgery, as in other fields of work, the general use of electricity for lighting, heating, and power purposes in hospitals throughout this and other countries enables the surgeon throughout the civilized world to procure the necessary power for operating his motor-driven instruments.

CHAPTER XI.

Required Efficiency of the Motor.

An electro-operative surgical machine for doing bone-work should measure up to the following requirements:

1. The speed of the cutter should not exceed that of 400 revolutions per minute; greater speed renders the bone-graft inert by burning it, and

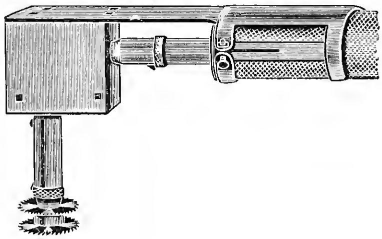


Fig. 23.—Right angle arm used in deep wounds or in places which cannot be reached by straight arm. To this all cutters or instruments can be attached, such as saws, drills, etc.

thus acting as a foreign body, which is liable to cause suppuration.

2. Motor should be sterilizable.

3. The weight of the motor should not be less than four pounds, and not over twelve pounds.

4. The motor should be universal.

5. The motor should develop enough power to drive all cutters or instruments used in bone-work.

6. The switch should be on the handle of the motor, so that it is always at the finger ends,

thus permitting easy and convenient control of the electric current.

7. The chuck should be simple, so that all varieties of cutters can be readily adjusted. The motor should be so constructed as to give perfect

Fig. 24.—Showing T-wrench in position in motor chuck, and small steel bar passing through handpiece and shaft ready for removal of chuck to be sterilized.

control and guidance to the motor-driven instruments, in all wounds, and at all angles (Fig. 23).

8. All cutting instruments should be constructed similar to those long used by artists for working hard materials, and should be of suffi-

cient variety to meet every requirement of bone-work, such as saws, drills, burrs, twin saws, dowel cutters, cranial cutters, trephines, etc., etc.

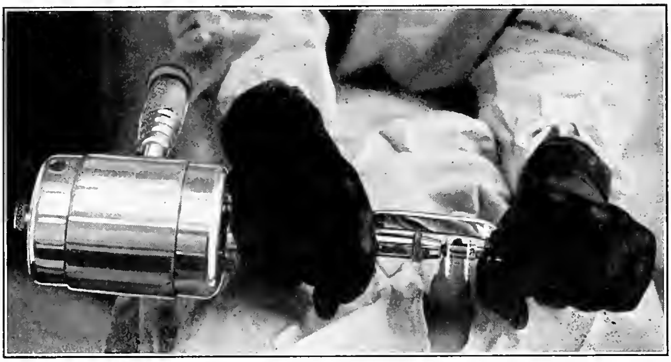


Fig. 25.—Illustrating extra guide handle in position on sterilizable motor; also, showing how it should be held while operating parallel saws. Displays sterilized motor without shell.

The original slow-speed motor, described in this chapter was devised and perfected by the

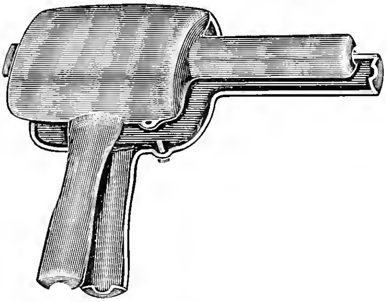


Fig. 26.—The author's sterilizable shell, which snugly covers motor. Used when one does not wish to sterilize the motor.

author, and fulfills all of the above requirements. All cutters are attached directly to the shaft which passes through the handpiece (Fig. 24);

the handpiece is cast integral with the body or housing of the motor, and is a part thereof. This enables the surgeon to hold the cutter firm and rigid while operating (Fig. 25).

The motor is sterilizable, and can be used without the shell; however, it is so constructed that a shell can be used over the motor, if so desired (Fig. 26). In a CLEAN case it is not necessary to sterilize the motor, as the shell is sterilized, which covers the entire motor, and the unsterilized motor cannot come in contact in any way with the part being operated upon or with the operator.

CHAPTER XII.

Description of the Author's Motor Instruments or Cutters and Accessories.

The author's electro-operative bone instruments consist of a universal motor, *i.e.*, one that will operate without adjustment, on either direct or alternating current, and in varying cycles. Stock motors are made 110 V. 60 Cycle; higher voltage and odd cycle are made special.

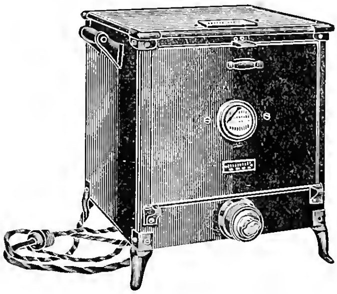


Fig. 27.—Electric hot air sterilizer with thermostatic control used for sterilizing the Geiger motor.

To have convenient control of the speed of the motor it is quite essential to have the hand-switch at thumb or finger ends. This switch is at the junction of the handle and body of the motor, and by a motion of thumb or finger the electric current is turned on or off.

If the surgeon desires a motor with different speeds, this is obtained by using a foot switch, especially constructed to be used with the author's

motor, and which gives eight different speeds. The foot switch, however, has its disadvantages, for should the surgeon wish to move from one side of the table to the other, or change his position, he must move the switch or have it moved to whatever position desired.

The motor weighs approximately four pounds, and has a handle and handpiece cast integral with

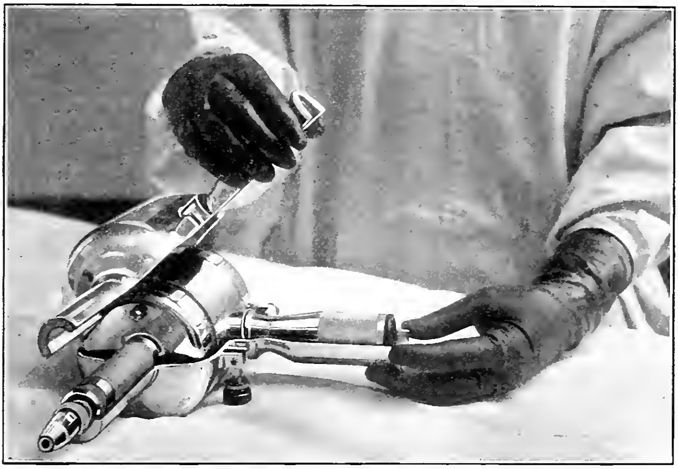


Fig. 28.—Displaying author's unsterilized motor being placed in sterilized shell. Chuck having been sterilized, nothing unsterilized can come in contact with operator or field of operation. Shell is held firmly together by thumb-nut.

the housing of the motor and at right angles with each other; both are cast integral with the body of the motor. The handpiece permits the surgeon to hold the cutters perfectly rigid while they are in operation.

This motor will stand a very high temperature; the temperature used for sterilization of motor

is 250° F., which insures complete sterilization within thirty minutes. However, should the oper-

Fig. 29.—Shows the author's motor being used without sterilizable shell.

Fig. 30.—One of the positions in which the motor may be held, giving firmness to motor and cutters. Sterilizable shell covers motor.

ator prefer to use the sterilizable shell (Fig. 28), it is not necessary to sterilize the motor, only after operating on pus cases, as in caries and necrosis,

where a motor burr should be used in removing diseased bone. It would not matter in a case of this kind whether you used a sterilizable shell to cover the motor or not, as it could not fit tightly enough to prevent some of the infected material from getting within the sterilizable shell. The author feels much more secure in sterilizing the entire motor.

The sterilizable shell is made of sheet brass,

Fig. 31.—Sterilized chuck being attached to motor.

nickel-plated. It is quickly adjusted and easily removed.

The chuck (Fig. 31), as devised by the author, is very simple and effective. The instrument to be used by the operator can be quickly adjusted or released by pulling forward the ring over the spring to which the pin is attached, thereby forcing the tapering pin down through the shank of the instrument; this causes the cutter to be firmly and rigidly fastened within the chuck. If the

operator wishes to release the instrument, he can do so by pulling the ring back over the spring, which releases it; the spring raises the tapering pin out of the shank of the instrument; the instrument can now be removed from the chuck.

The chuck is so constructed that it can be easily removed from the shaft, to which it is attached by threads or grooves, in order that it may be sterilized when using the shell.

CUTTERS AND ACCESSORIES.

The author's armamentarium consists of an electric motor, electric-driven instruments and accessories used in bone work, which are as follows:

Drills. Five in number; sizes ranging from 7/64″ to 3/8″. They are of the twist drill type, and penetrate bone very quickly, with great ease and with little friction, and do not burn or char the bone.

The smaller sized drills—5/64″ and 7/64″—are used for making holes in transplants and recipient bone, for kangaroo tendon, to hold the transplant in position. The 1/8″ drill is used to make holes through the transplant and recipient bone for bone-pegs to hold the transplant in position. The 3/16″ drill is used to make holes in pieces of bone broken away from the main bone, such as condyles, protuberances, etc., and into the principal bone to receive the bone-pegs to hold said pieces of bone, condyles, etc., in position. The 3/8″ drills are used in case of fracture of the hip to

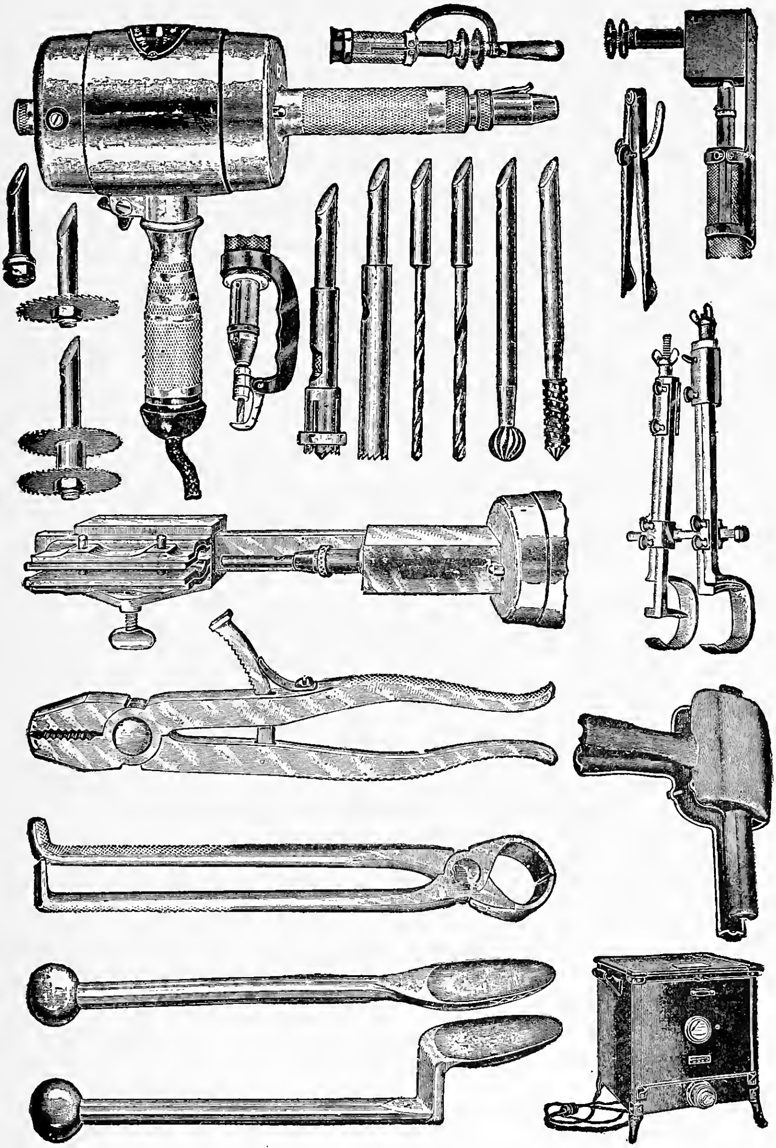


Fig. 32.—A complete set of the author's bone instruments, motor sterilizable shell, electric sterilizer, cutters, and accessories.

bore holes through the greater trochanter, through the neck, and part way through head of the femur, to receive the autogenous dowel or spike so as to hold the fractured neck in position.

Saws. The single saws are of ten assorted sizes, ranging from ¾″ to 2″ in diameter, mounted on a short mandrel or shank, which

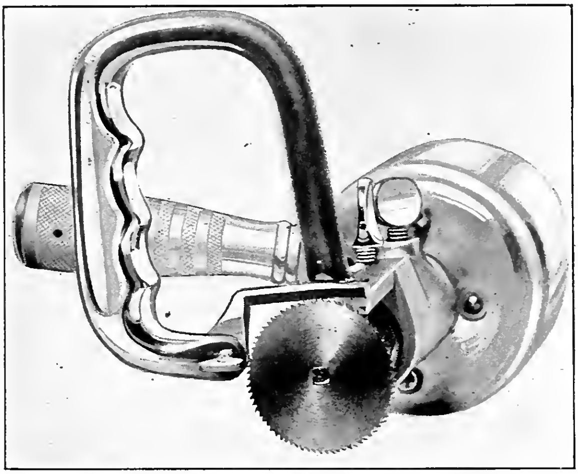


Fig. 33.—The author's latest idea of motor bone saw. The handpiece, being directly behind and above the cutter, gives the operator perfect and continuous control of the instrument while it is in operation.

is universal in size. The teeth of the saws are cross cut, and of different sizes and sets; being cross cut, they cut with great ease in living or dead bone. The set of the saw is very important, as is also the size of the teeth; there must be enough set so that the saw will not "bind" or produce friction, for friction will produce heat in substance that is as hard as bone, even if the

speed of the saw is slow. As previously stated, the speed of the author's motor will not exceed over 400 revolutions per minute while working, which insures against overheating of the bone, if the saw has the proper set. However, should there be friction by pinching of the saw, it will create heat, which may greatly interfere with the life of the cells of the bone transplant; or if the heat is great enough, it would burn the bone, and render it unfit for the desired purpose. The use of water for cooling the saw washes away the material which nature has so wisely provided, viz.,

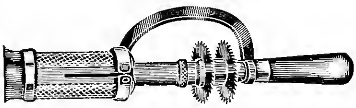


Fig. 34.—Extra guide handle for single or parallel saws.

blood and serum, which are essential for the immediate life and growth of the transplant. The single saw is used for removing bone-grafts from any location, and is also used in making a groove to receive the inlay.

Twin or Parallel Saws. Two circular saws of the same size placed parallel to each other on the same shaft; the distance between the blades varies from $\frac{3}{16}''$ to $\frac{1}{2}''$, so as to suit the location or needs of the case. The parallel or twin saws are used in removing transplants when two sides are cut parallel to each other, and also in preparing the recipient bone to receive transplants shaped in the above manner.

Mandrel or *shank,* for single or twin saws, is short, which brings the saw close to the hand-piece. The part of the shank or mandrel which

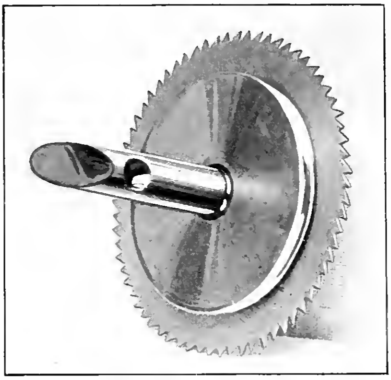


Fig. 35.—Two-inch single saw with saw-guard for regulating depth of saw, in position on mandrel, ready to be placed in chuck of motor.

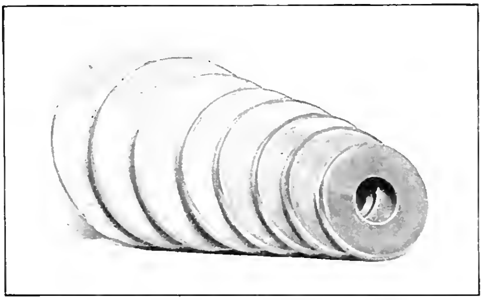


Fig. 36.—Saw-guards, eight in number, for regulating depth of saws.

receives the saw (as shown in Fig. 33) is square, and the hole in the center of the saw is also square. This prevents the saw from turning on said shank. The nut that holds the saw in place

on the mandrel is not required to be very tight; it can be brought tight enough with thumb and finger; a wrench is not required.

Saw-guards (as shown in Fig. 36) are eight in number, and the sizes range from ½″ to 1¼″ in diameter. They can be applied to either twin

Fig. 37.—Author's sharp-nosed burr used for enlarging medullary cavity, removing necrosed bone, etc.

or single saws, and are used to regulate the cutting depth of the saws.

Reamers or Burrs. These are two in number. No. 6 is an ordinary cherry burr, with 3½″ shank, and cutter ⅜″ in diameter. No. 7 was specially designed by the author, and has a sharp nose (Fig. 37). This burr can be used for making holes in bone, as well as enlarging medul-

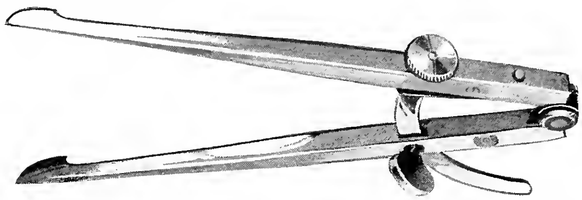


Fig. 38.—Author's caliper knives used in measuring and marking or laying out size and shape of grafts to be removed, and beds or cavities in which they are to be placed.

lary canal for the reception of the dowel or removing dead bone. The diameter of the burr proper is ⅜″. These burrs are of great use in the preparation of tunnels in cancellous bone for the insertion of dowel or peg transplants.

Caliper knives, No. 30 (Fig. 38) is a very valuable addition to a set of bone instruments, as the surgeon lays out his work with this knife. If the surgeon wishes to cut a graft ½" wide,

Fig. 38*A*.—Author's periosteotome. Anyone doing bone surgery will find this instrument quite convenient.

he sets his caliper knives ½ an inch apart, drawing them down over the periosteal covering of the

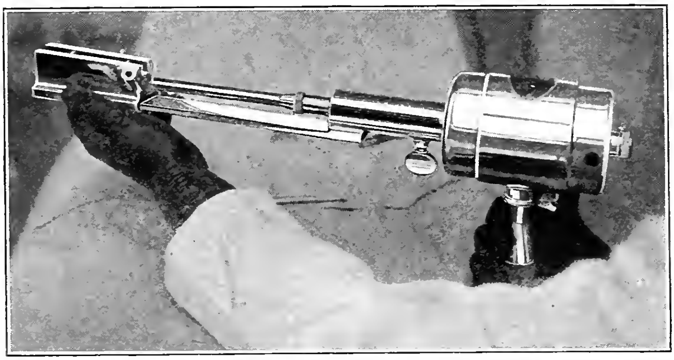


Fig. 39.—Author's tube-saw or dowel-shaper, with lathe attachment, in position on motor ready for action.

bone, making two incisions through the periosteum, exactly parallel with each other, and the same distance apart at every point. In cutting an intramedullary dowel the caliper knife is in-

dispensable; for you caliper the medullary cavity, and cut your dowel accordingly.

Periosteotome No. 38*a* was specially designed by the author. The handle, shank and all, is 4″ in length; the cutting part is ½″ wide; it is used

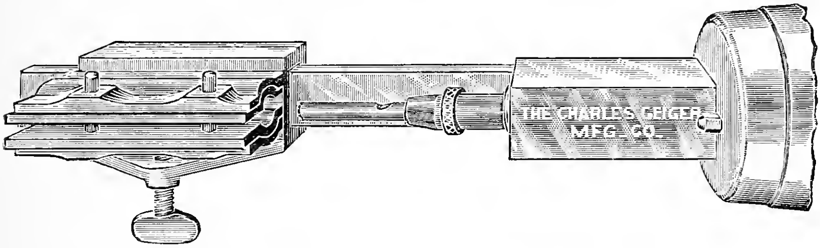


Fig. 40.—Tube saw or dowel shaper with lathe attachment in position, showing vise in which graft is placed and held firmly while bone-peg is being made; the hollow bar, which passes over handpiece of motor, is firmly fastened by thumb-nut to handpiece.

for loosening the periosteotome along the outer side of the two incisions made with the caliper knives.

Dowel shapers, or tube saws (Fig. 39), are

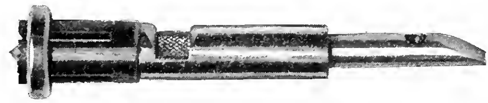


Fig. 41.—Author's motor trephine showing center pin, and guard with thumb-screw which govern depth.

three in number, ranging from ⅛″ to ⅜″. The ⅛″ dowel shaper is used in making pegs or nails to hold inlay grafts in position. The 3/16″ size is used for making dowels for pinning the broken condyles, spicula of bone, etc., in position. The large size (⅜″) is used for making bone spikes

or dowels to be used in fractures of the neck of the femur. The tube saw can be used with or without *the lathe attachment* (Fig. 40). However, it is much easier and quicker to cut a

Fig. 42.—Author's motor protected burr or cranial cutter with detachable handpiece. In position on motor ready for action.

dowel with the addition of the lathe attachment to dowel shapers.

The three different sized dowels made by the three different size tube saws fit snugly in the holes made by the 1/8″, 3/16″, and 3/8″ drills. Should an attempt be made to use the dowel cut-

ters or tube saws without the lathe attachment, it is necessary to have two assistants to hold the bone-graft firmly, and push it gradually into the tube saw.

Trephine No. 22 (Fig. 41) was designed by

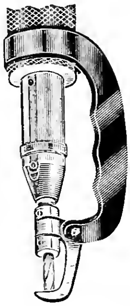


Fig. 43.—Author's protected burr or skull cutter.

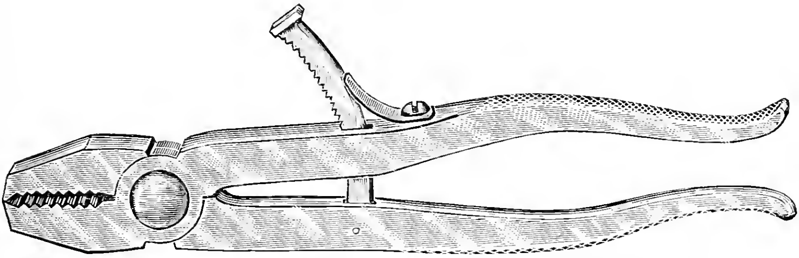


Fig. 44.—Author's bone-graft retaining forceps with projecting jaws, for the purpose of passing down into saw-furrow to remove graft from its original bed. Also shows ratchet on forceps which locks jaws and holds graft firmly while being placed between the fractured ends of bone.

the author, and is the most ingenious and valuable instrument in the set. It has a thumb-nut by which you regulate the cutting depth; and by feeling your way you can absolutely prevent injury to the dura. It cuts a hole ½″ in diameter,

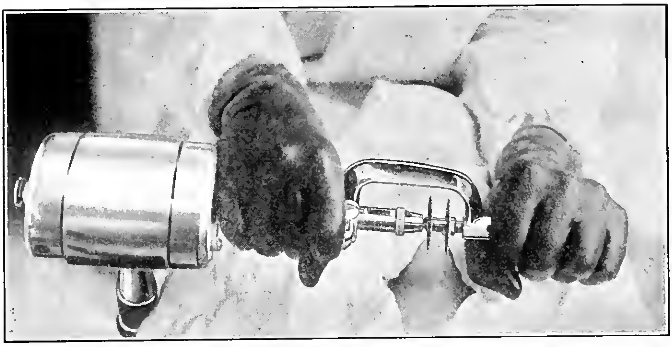


Fig. 45.—The author's twin saws with extra guide handle, in position on motor ready for operation.

giving ample room through which to inspect the dura or introduce the skull cutter.

Protected burr or skull cutter, No. 33 (Fig. 42), in position ready for action as planned by

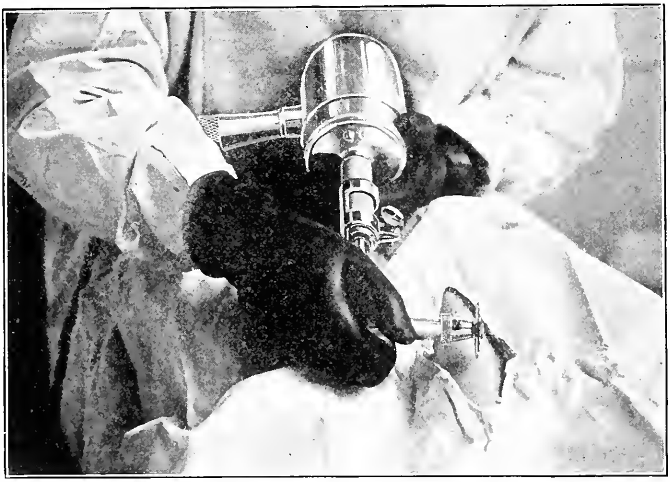


Fig. 46.—Author's right-angle arm in position on sterilized motor, with single saw attached ready for operation.

the author, has a shoe or protector which dissects the dura from the skull, and also prevents the burr from injuring the soft parts. The burr is $\frac{1}{8}''$ in diameter. The part of frame which forms the shoe is so constructed that the *detachable handpiece* (Fig. 43) is fastened thereon and enables the operator to give great force to the cutter or burr, and also to have absolute control of the instrument at all times.

Bone-graft retaining forceps, No. 38 (Fig. 44), as designed by the author, is a very important instrument to anyone that is doing plastic bone

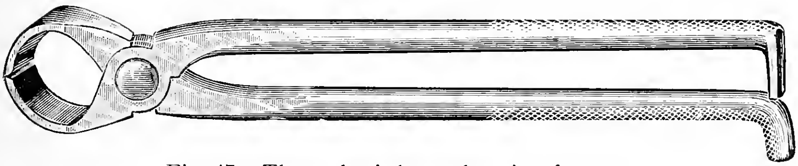


Fig. 47.—The author's bone-elevating forceps.

surgery. It is used in removing the graft from its bed, and placing it in position. The nose of the forceps is $\frac{1}{2}''$ wide, which projects, as shown in the above cut, which makes it easy to remove a graft from its bed. The forceps is also supplied with a ratchet, which holds the jaws firmly in position wherever placed, and prevents the graft from getting loose from the forceps, which is of great importance. Many a graft has been rendered unfit for use by being dropped accidentally on the floor while using the ordinary forceps. After the graft is once in the jaws of this forceps it cannot get away unless released.

Bone-elevating forceps, No. 37 (Fig. 47), was devised by the author, and is used for lifting the ends of the fractured bones into position, or hold-

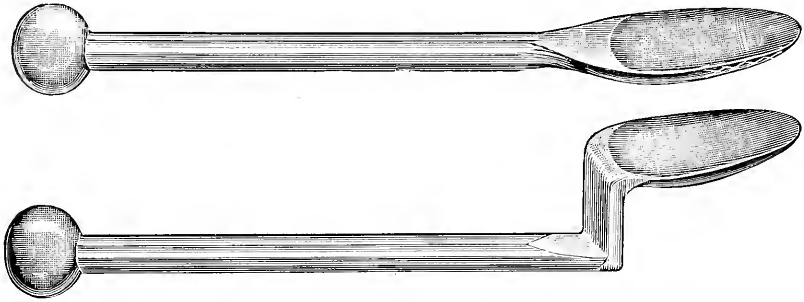


Fig. 48.—Author's bone skids or elevating spoons, used in breaking up adhesions in ununited fractures, and to serve as a pry in adjusting fractured ends of bone.

ing ends firmly while they are being prepared to receive the graft or inlay, or intramedullary dowel.

Bone-elevating spoons or skids, Nos. 35 and 36 (Fig. 48), are two in number: one straight and the other curved. They are specially con-

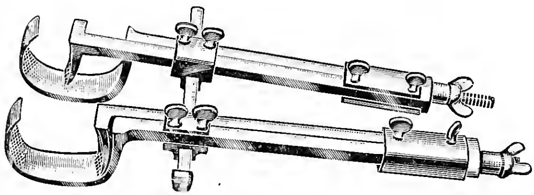


Fig. 49.—Author's bone-clamp, which is indispensable in getting out sliding inlay grafts. The clamp is applied; the ends of the bone are brought into apposition and held firmly by the clamp, while sliding graft is removed from one fragment or the other with twin or single saws and placed in position. The clamp does not interfere with the removal or with the placing of the graft in position, being open on upper surface, as illustrated.

structed by the author, and are used for breaking up fibrous adhesions between the ends of un-united fractures, and prying or elevating ends of fractured bones into position.

Fracture clamp (Fig. 49), is used to hold the fractured ends of the bone in position, while the inlay graft is cut from above or below the fracture. The *Geiger* clamp is so constructed as to enable the surgeon to cut inlay graft, remove the graft from its original bed, and put it in its new position, while the clamp is applied, and holds the fractured ends of the bones in perfect anatomical relation.

CHAPTER XIII.

Orthopedic and Fracture Extension Device.

In all fractures of the extremities it is essential that perfect and continuous extension be made upon the injured limb while the dressing is being applied. This cannot be successfully done unless

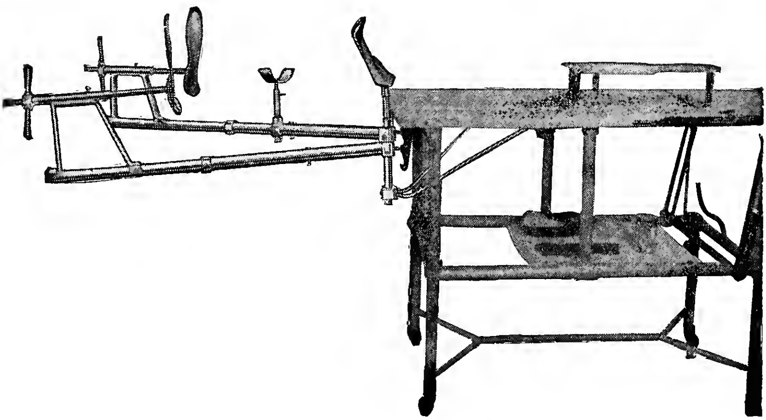


Fig. 50.—Author's extension device attached to operating table with shoulder- and head- support; saddle raised, extension-arms raised, ready for application of bandages or dressing to hip or lower portion of body.

the surgeon has at his disposal a device made for such purpose.

The Charles Geiger orthopedic and fracture extension apparatus fills all the requirements. It can be fastened to any operating table (Fig. 50), which is accomplished by means of three clamps.

This extension obviates the necessity of having a special table made for such purpose, as it can be applied to any operating table in a moment's time when desired, and can be removed quickly when no longer needed, and placed in a corner out of the way until it is again required, which makes it most valuable.

When knocked down it is so constructed that it occupies only a small space, the longest part being but three feet in length. Should the operator desire to use it at some other hospital or hospitals, it

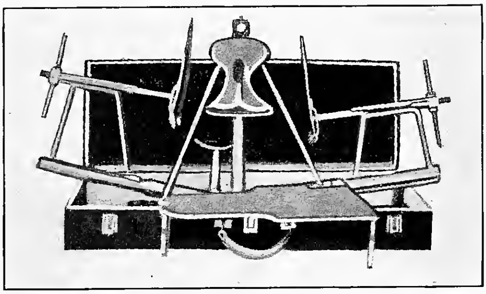


Fig. 51.—Author's extension device knocked down, ready to be placed in carrying case.

can be placed in a carrying case (Fig. 51), specially constructed for such purpose. Not only is this device easily portable, but you can do anything with it that can be done with any fracture or orthopedic table; it fills every requirement called for in orthopedic or fracture work.

If extension of the arm is necessary, as in fracture of the neck of the humerus, or any other part of the arm, perfect extension and counter-extension can be made with this device (as shown

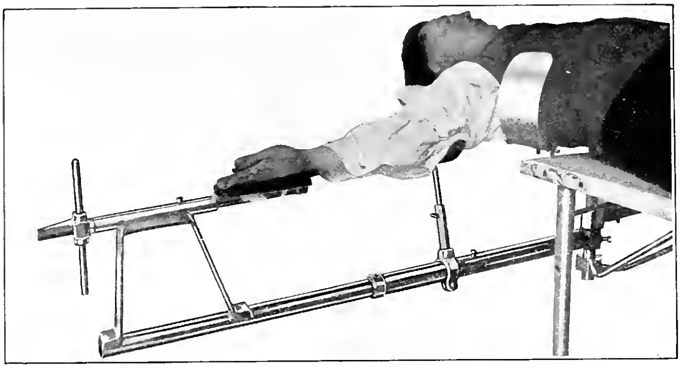


Fig. 52.—Author's extension device with hand in position on handpiece and arm-rest; also, counterextension produced by piece of plate steel four inches wide, shaped to chest.

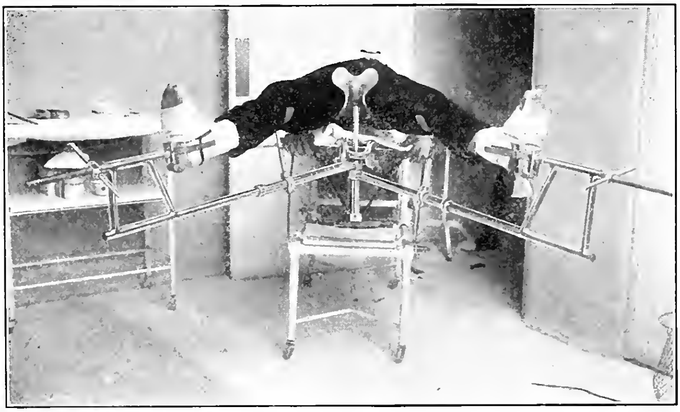


Fig. 53.—Author's orthopedic and fracture extension device, with subject's legs in extreme abduction (Whitman's position), for treatment of fractures of the neck of the femur. Displaying the perfect saddle, which is so constructed that it absolutely prevents any pressure upon the urethra. Also shows leg support just above the knee.

in Fig. 52). The counterextension is accomplished by a piece of steel plate, 4″ wide and 12″ long, shaped to the chest. When traction is made on the arm, the counterextension brought about by this device does not interfere with the movements of the chest in breathing. This is very important, as in the breathing of all persons

Fig. 54.—Side-view of author's orthopedic and fracture extension device, with saddle, and shoulder- and head- supports in position, ready for applying dressings to hip or back.

under anesthetic, while major work is being done, the motion of the chest should not be hampered. The broad band of cloth used in other devices is extremely dangerous, as it seriously impairs breathing, and endangers the life of the patient under such conditions; it should be condemned.

The *Whitman position* for treatment of frac-

tures of the neck of the femur—extreme abduction—is easily accomplished with this device (Fig. 53). The rotation of the femur is controlled by the footpiece or plate. Fig. 53 also shows the saddle used which protects the perineum, and

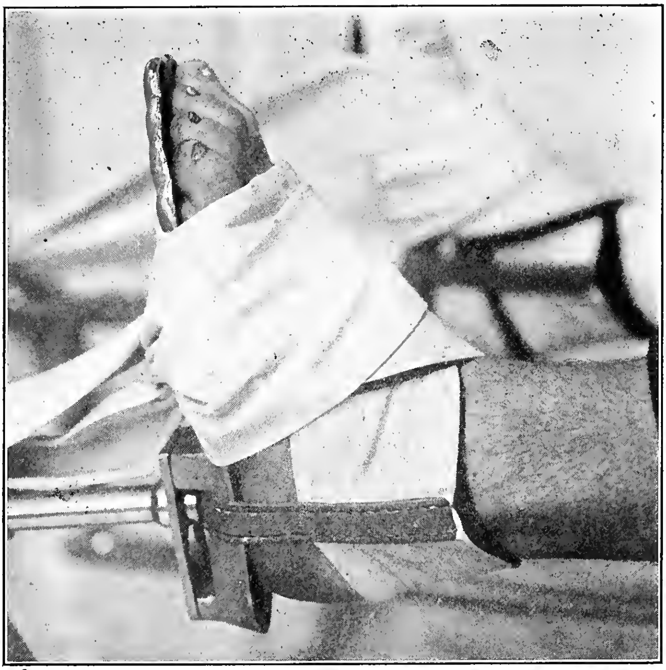


Fig. 55.—Displaying footpiece of author's extension device. Foot fastened in position, ready for extension of limb.

especially the urethra, from undue pressure or trauma. The saddle gives perfect counterextension, and with head- and shoulder- supports (Fig. 56) elevates the body and hips, so that plaster-of-Paris dressing or other dressings can be applied to the lower portion of the trunk or hips

without any interference to the operator. Traction can be applied to a limb in any degree of abduction, which is frequently of great advan-

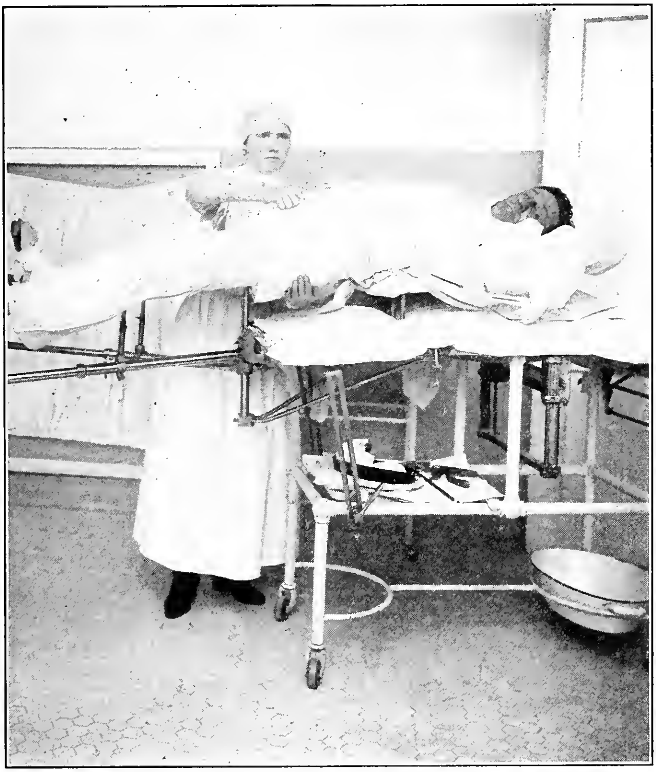


Fig. 56.—Demonstrating the application of spica bandage to hip. Showing clearance under body, with pelvis resting by saddle, and the upper portion of body resting on head- and shoulder- supports.

tage, especially in fractures of the upper third of the femur. As in all other fractures, the neutral position should be made the most of. In other words, the displacing forces should be overcome

by placing the limb in such position as to bring about the desired results. Reduction should be completely accomplished. If unable to do so by external manipulation, the open method should be resorted to, and the bones placed in perfect apposition and the limb in a neutral position, after which a plaster-of-Paris dressing should be applied without the position of the limb being

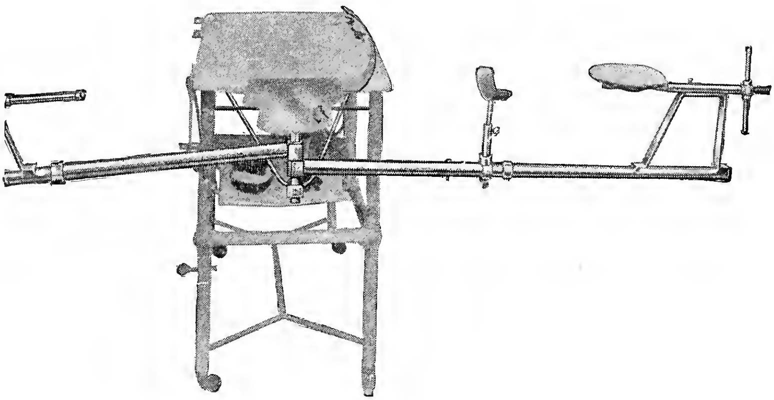


Fig. 57.—Author's extension device, with head- and shoulder- rests in position; extension-arms at right angle with table, ready for extension of patient's arm.

changed or the traction being released the slightest. This dictum applies in all cases in reduction of fractures, whether operative or non-operative methods are employed, and irrespective of the type of internal fixation, if such is to be used. No internal fixation method—viz., steel plate, bone inlay, intramedullary dowel, etc.—will for any length of time stand the pulling of strong muscles at cross-angles to the fractured part. Kangaroo

tendon will break, wire will cut through bone, screws will pull out, bone transplant will necrose and break, if continuous pressure is applied thereto.

In fastening the feet or hands to the foot- or hand- piece of the author's extension device, a retaining bandage of double ducking 2½" inches wide and 3 yards long, is used (Fig. 55), in the center of which has been sewed a piece of Mexican felt, 3" wide and 15" long; this acts as a protection-cuff for the ankle or wrist. Across this bandage, 1½" to the right and 1½" to the left of the center, are sewed two straps; one about 10" long, having holes in it an inch apart, and the other about 3" to 3½" long, having a buckle on the end. When the bandage is in position these straps run parallel with leg, and are passed around the footpiece, drawn tight, and buckled; this holds foot firmly in position. In placing the bandage to the foot, the middle of it is firmly applied over the tendo Achillis; the right end is brought up on the right side of the foot, and the left end on the left, and so on, until the foot is firmly fastened. You are now ready to make your extension by turning the hand-nut of the device.

In applying plaster-of-Paris bandage to leg or arm, while extension is being made with the author's extension device, the cast is extended down to ankle or wrist, and is allowed to partially dry; then the extension is released, and retaining bandage is removed, after which the wrist and hand or ankle and foot are covered with a plaster bandage.

Geiger-Murphy Orthopedic and Fracture Extension Table. The outfit consists of a modified Murphy hydraulic operating table in conjunction with the Geiger orthopedic and fracture extension device. This device comes complete with all necessary attachments for orthopedic and fracture work. Plaster casts or dressings can be applied

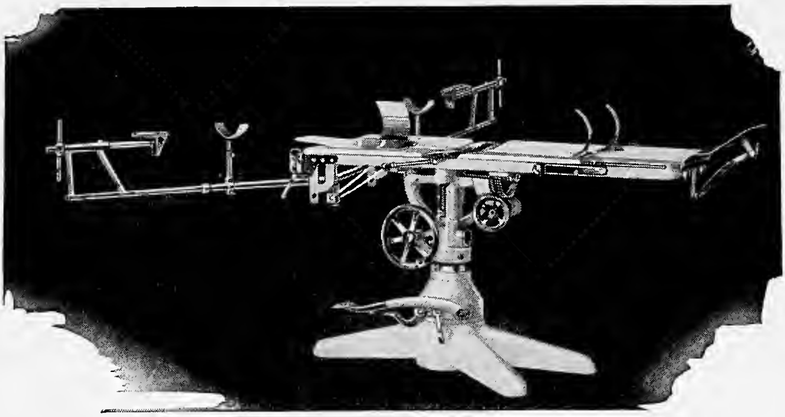


Fig. 57*a*.—Exhibits extension arms of the *Geiger-Murphy* fracture and extension table, in position with saddle, which fits the perineal region perfectly, and gives perfect counter-extension, used in extending the lower limbs in reduction of fractures in the open or closed method; also for the application of internal splints (bone-grafts) and the application of plaster-of-Paris and other dressings to the limbs, hips and body.

to hip, back, or any part of the body or limb without obstruction and with ample clearance.

A particularly noteworthy fact is that the operating table is not in the way when applying dressings to the extremities. Perfect and continuous extensions can be secured on the smallest child as well as the largest man. The extension

arms are fitted with attachments for either hand or foot, with rests for arms and legs, and may be used at any angle from 180 degrees to practically a parallel position. Extension is secured by a steel screw on each of the extension arms. All attachments are heavily and well constructed.

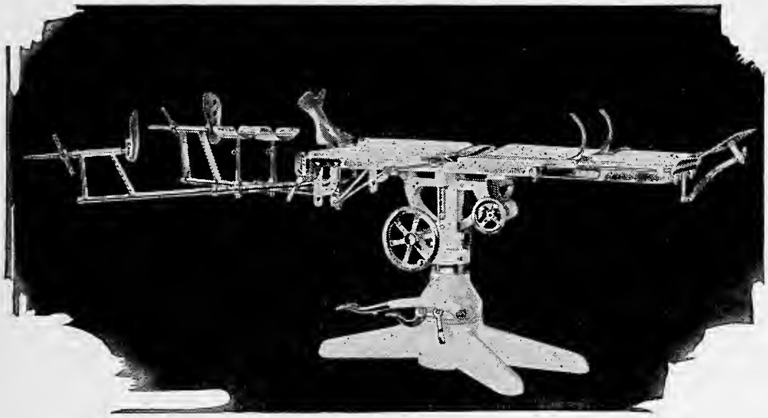


Fig. 57*b*.—Displaying *Geiger-Murphy* fracture and extension table, with head- and shoulder-rest and extension arms in position. Extension arms at right angle with table for the extension of arms for the reduction of fractures by the closed method, or for the open method of reducing fractures, the application of internal splints (bone-grafts), or surgical dressings, such as plaster casts, etc.

CHAPTER XIV.

General Remarks on Technic.

The general preparation required for bone surgery does not differ from that demanded by any other major surgical procedure. The local preliminary preparations are made the day previous to the operation.

The limb or field to be operated upon is prepared as follows: The skin is scrubbed with soap and boiled water, shaved, and washed with alcohol. After thoroughly drying the part, a half strength of the common tincture of iodine is applied to the field, and then it is covered with a sterile gauze, which is fastened to the part by adhesive plaster. At the time of the operation the skin is mopped thoroughly with tr. iodine half strength, then apply alcohol freely, removing the tincture as completely as possible. The use of antiseptics, excepting the iodine, on the day of operation is absolutely useless; in fact they are harmful, for anything that is strong enough to destroy pyogenic germs will also destroy the living bone-cells, if perchance it should come in contact with the same. Anything that inhibits or kills the growth of the living cells, such as bichloride of mercury, carbolic acid, or any chemical of such nature, should not be used in the preparation of the operative field at, or just prior to, the time of operation.

If the above antiseptics are used on the day or at the time of operation, they should be removed as completely as possible by washing with alcohol, for if they are allowed to remain and come in contact with any part of the bone or graft they will destroy the cells of such part, inhibit growth, and invite infection. It is quite evident that a special technic is required in bone surgery. Rigid operative asepsis must be maintained; the application of the rubber gloves to the surgeon's hands must be under the most rigid technic, viz., the gloves must be thoroughly sterilized, then dried, after which the gauntlet of the glove must be turned back. The nurse, with gloved hands, now slips her fingers between the reversed gauntlet on either side of the glove, and produces traction, which permits the surgeon to introduce his hand well into the glove. The outer or external surface of the gloves must not be touched or come in contact with the ungloved hands of the surgeon or of anyone else, or with the prepared or unprepared skin of the part to be operated upon, as it is impossible to sterilize the skin under such conditions.

After a free incision has been made, the skin is pulled back. Sterile towels are now fastened in the wound, between the surface of the incised skin, so that the instruments or gloved hands of the operator cannot come in contact with any part of the skin.

To emphasize, *a special technic is required in bone surgery.* Rigid operative asepsis must be

maintained. Great care must be taken not to wound or lacerate the tissues any more than is absolutely necessary. The vitality of the transplant depends largely upon the care in removing it, and retaining it in as nearly a normal condition as possible. The native blood and the serum should be kept on the surface, and within the graft. Consequently the change from the old to the new location, or bed, must be made quickly, so that nature's life fluid will be conserved and not desiccate or drain away, should there be a temporary delay between the removal of the transplant and the placing of it in its new bed. It must not be placed, or an attempt be made to preserve it, in saline or other solutions, because they remove that which should be retained—the fluids of life (blood and serum), which sustain the vitality of the transplant.

In case of delay, the graft should be wrapped in sterile oil silk to exclude the air and retain the moisture. Water should never be applied to a wound in order to keep the motor saw or other cutters from burning the bone, or for cleansing purposes, for it invites infection, and removes the vital substance you wish to retain, and in fact always does more harm than good.

In controlling hemorrhage in plastic bone work, the tourniquet is counterindicated, because of the danger of reactionary hemorrhage with clots in the deep part of the wound, which would interfere with the vascularization of the transplant. To control the hemorrhage from small vessels

and capillaries of the soft parts, the wound is packed with gauze thoroughly wrung out of *hot* normal salt solution. Arteries and veins of any size are picked up with hæmostats, and tied with absorbable ligatures. Great care must be exercised in seeing that all bleeding is controlled; many operations have failed to give the desired results because of the lack of the proper attention given to the complete stopping of hemorrhage in the bone, as well as in the soft parts. Then with complete hemostasis and the transplant in position, the wound is closed without drainage, in layers with absorbable sutures, and covered with an abundance of sterile gauze, sufficient to give proper protection to the wound without further interference for six to eight weeks, or until we have bony union.

The real success of the transplant depends largely on the actual contact between the osteogenetic surface of the host and the osteogenetic surface of the transplant. Periosteum, fat, fibrous tissue, muscle, or blood-clots of any considerable size prevent the graft from uniting to the host, to the extent of their interposition. Too much cannot be said in regard to the injury of the superficial cells of the bone-graft, or the contacting surface of the host. As previously stated, great caution should be exerted in preventing frictional overheating of the sawed surface by the *speed* of the electric saw, also from contacting the graft to its host so tightly as to produce superficial pressure necrosis.

I again wish to emphasize the importance of bearing in mind that the antiseptics sometimes used, if brought in contact with the superficial cells of the bone-graft or its host, may do irreparable injury by destroying the cells of such surface; that by the time the injured cells have died, become absorbed and cleansed away, the underlying layer of living bone of the host and the graft will have healed over, and will fail to unite or to graft over such surface.

An ideal transplant contains periosteum, cortical bone, endosteum and marrow. If used as an inlay, the corresponding layers of the host should come in contact with the same layers of the transplant. The inlay graft should be taken from as near the location of the fracture as possible (Fig. 73, Geiger method); for a transplant having the same consistency as the host has proved superior to one removed from remote or distant parts of the body.

CHAPTER XV.

Elements Essential in a Transplant for Continued Success.

THE ESSENTIAL ELEMENT OF A TRANSPLANT IS CORTICAL BONE, BECAUSE OF ITS RESISTANCE TO CHANGE OF FORM, BY WHICH IT GIVES SUPPORT TO ITS HOST; ITS SMALL VASCULAR SUPPLY, WHICH ALLOWS IT TO RETAIN ITS VITALITY FOR A CONSIDERABLE LENGTH OF TIME AFTER TRANSPLANTATION; ITS CAPABILITIES OF BEING SUSTAINED BY A SMALL AMOUNT OF NUTRITION; AND ITS ACTIVE OSTEOGENETIC PROPERTIES CAUSE IT TO GRAFT WITH RAPIDITY AND FIRMNESS. The early vascularization of the transplant is materially aided by the periosteum and endosteum. It has been repeatedly demonstrated and proved to be a fact that small fragments of bone retain their vitality and graft better and quicker than larger fragments. So the transplant should be composed of the smallest amount of bone that will fulfill all the requirements.

In intramedullary dowel, bone-peg, or spike, the periosteum must be removed from the parts that have bone contact, and which extend up into the fractured ends of the recipient bone. If the

ends of the fractured bone come together, the dowel should be without periosteum. If considerable space exists between the ends of the bone, that part of the transplant not covered by the recipient bone should possess all of the periosteum possible. This demonstrates the reason why the fibula makes such an excellent transplant. The proper fitting of the transplant to the host often furnishes fairly good fixation.

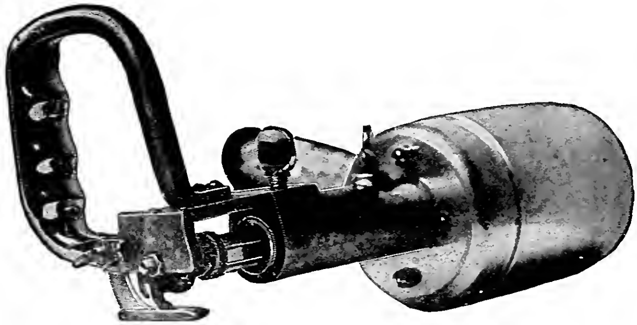
It may be necessary at times, however, to reinforce the fixation by bone-pegs or by the use of kangaroo tendon sutures passed around the transplant, and through the holes drilled in the host and graft. Wire nails or any metallic substances should never be used as fixation of transplants to hosts, as this fixation can be accomplished with autogenous bone-pegs. Before completing the fixation of the bone-graft it is quite essential to neutralize the muscular action by position, and to neglect this will allow a spasmodic movement between the transplant and the host. The position of the limb or part operated upon should be a position of normal alignment and rotation, in which there is complete relaxation of the muscles acting upon the area of autoplasty.

Should the above not be carried out in detail, irregular movements or leverages will either dislodge the transplant, shear it across, or cause it to cut through its bed or host, the course depending upon the direction furnishing the least resistance.

To immobilize the limb, a close-fitting plaster-

of-Paris cast cannot be excelled. The cast is applied including one or more joints above and be-

A



B

Fig. 58.—*A,* Geiger motor plaster-of-Paris cutter; *B,* plaster-of-Paris cutter in operation. Note the firmness with which the machine can be held.

low the autoplastic work or repair. The fixation must be complete and continuous, until staple

grafting or bony union has occurred between the inlay and the recipient bone.

It is understood that the surgeon has at hand all instruments and appliances necessary to carry out successfully all details of such operation. All preparations having been previously made on the part to be operated upon, a generous skin incision is made, just overlying the point of fracture. When possible, the incision should be made on one side or the other of the intended bed or site of the transplant. The fascia and muscles overlying the point of fracture are opened by scalpel and blunt dissection, and the region of fracture well exposed. All bleeding vessels are ligated with plain catgut; the blood-clots and débris are removed from the ends of the fragments. Great caution should be used not to produce any more trauma than is absolutely necessary. In the retraction of powerful muscles enough trauma has been produced to cause slough; this is more likely to occur when a short incision has been employed. Trauma has also been caused by the careless use of the motor saws, clamps, elevators, dull instruments, etc. A skin incision of sufficient length, or large enough to give ample room in all operative fracture work, is very essential.

The periosteum, if intact, is incised with the caliper knives, which make two parallel incisions. The incisions are made longitudinally, and the periosteal strip between the incision is cut transversely. Then the periosteum is pulled back on either side to inspect the broken ends of the bone.

In fresh fractures, if the operator has decided to use the inlay graft, material for such graft can as a rule be taken from the fragments themselves, unless the fracture is of comminuted type. As a rule, a graft 3" to 4" is long enough, but should the surgeon be dealing with an ununited fracture, the length of the graft depends upon the amount of eburnation. In ununited fractures the graft should extend at least ½" to ¾" into healthy bone, on each side of the fracture.

In taking the graft from one or the other ends of the fresh fractured bone, the caliper knives are set at the width that the transplant is to be made; then they are placed over the proximal end, at the seat of fracture, and drawn up towards the body from 4" to 5", in a straight line. They will make two incisions through the periosteum. Now we use the periosteal elevator to shove the periosteum back on either side, about ⅛".

We now place the caliper knives at the seat of fracture, over the distal fragment of bone, drawing them down the bone 2" to 2½"; we again use the periosteal elevator to push back the periosteum. We can now use either the single or parallel saws to remove the graft above and below the fracture.

The author prefers the single saw, on account of being able to bevel the inlay and the host or bed, so that the inlay will not fall into the medullary cavity. In cutting across each end the author uses ⅛" drill, making the drill holes about ⅛" inch apart into the medulla, after which a

sharp chisel is used to cut loose the graft at the end still intact. We now slip the proximal or long graft to the lower end of the bed, giving us a continuous bone transplant 1½″ below and

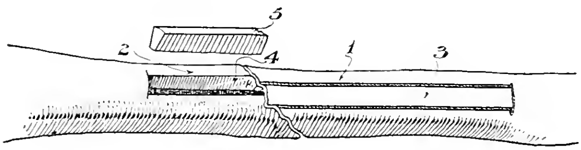


Fig. 59.—Illustrates sliding-graft being removed from fragment (*1*) and graft (*3*), to be placed in space (*4*) and equally divided between fragments (*1* and *2*). Piece of bone (*5*) to be made into pegs for use in holding graft in position, as shown in Fig. 60.

above the fracture, bridging across the seat of fracture, having previously removed the short graft out of which pegs are made to fasten the

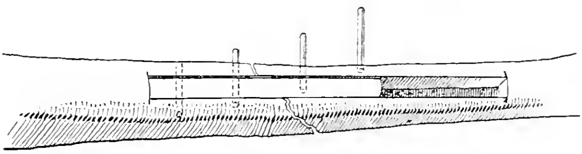


Fig. 60.—Illustrates the sliding-graft in position, bridging across the fractured ends of bone. The short graft is made into pegs to hold transplant rigidly in place; the remaining fragments of bone can be placed in that portion of the bed from which the transplant has been removed.

inlay in position, or, in other words, changing position of the transplant—the short one above, and the long one below.

Pegs are far superior to kangaroo tendon for

making secure the graft in its bed. The bone-pegs are made $\frac{1}{8}''$ in diameter; holes are made for these pegs through the host and through the graft (as shown in Fig. 60). If there is any bone left, we take and place it in the hole caused by the removal of the long graft from the proximal fragment of fractured bone into its new bed. As shown in Fig. 60, bone-pegs are also used to fasten small fragments in position. The periosteum should be protected during the operation, so that all parts of the inlay are eventually covered by it. I believe it a good practice to sew the periosteum covering of the transplant and the periosteum of the recipient bone together. By this arrangement the periosteum is made to completely cover the transplant. If a good fit of the transplant is obtained, and the work is done in proper manner, the inlay always lives, grafts itself to the adjacent or recipient bone, a transformation takes place, and the result is that it becomes a permanent integral part of the recipient bone, the same as bone-pegs or intramedullary dowels.

CHAPTER XVI.

The Use of an Inlay Graft.

The inlay transplant can only be used in certain cases. It is most effective where osteogenesis of the end of the broken bones is to a certain extent destroyed, or where osteogenetic action is required. I believe that an inlay graft is preferable, especially when taken from the fractured

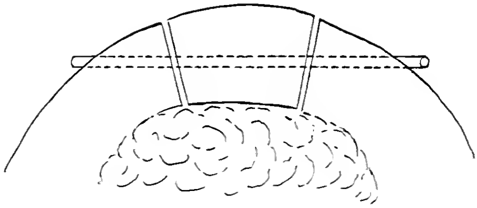


Fig. 61.—Cross-section of the inlay transplant of a long bone, showing the manner of its fixation by bone-pegs. Also shows bevelled edges making the graft wedge-shaped. The motor single saw is used in removing such a graft.

ends or fragments of the bone, or from near the location where it is transplanted; and the inlay, as it does, brings periosteum to periosteum, cortical bone to cortical bone, endosteum to endosteum, etc., lives and grafts more readily than does an intramedullary dowel (Fig. 61).

An inlay graft should comprise four different tissues, namely, periosteum, compact bone, endosteum, and marrow substance. The inlay method is the only method that permits coaptation of each of these individual elements to those of the re-

cipient bone. An inlay graft, however, is limited in its application. In a vicious fracture that requires considerable strength to hold it in position, the intramedullary dowel is much superior; in fact, it would not be good surgery to use any other means of internal fixation in such condition. The inlay transplant does not furnish sufficient strength of fixation to be reliable in fractures of unsupported single long bones. It is a matter for the surgeon to decide whether bone-pegs or

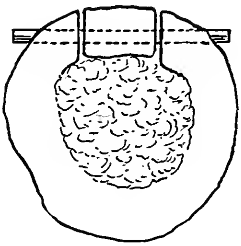


Fig. 62.—Cross-section of long bone with rectangular inlay graft held in position by bone-pegs. Graft may be removed by either parallel or twin saws.

kangaroo tendons are used to fasten the inlay to the recipient bone (Fig. 62). Extreme caution must be used in applying the outer fixation or plaster cast. The fixation of the inlay, however, is very materially increased by the use of bone-pegs in holding the transplant in position. Should the pegs holding the inlay in position be broken during the application of the outer dressing, displacement of the graft is almost sure to occur; or should the outer dressing or plaster cast not be snugly applied, on moving the limb, or should

spasmodic contraction occur, motion will be given to the fragments, and the desired results from the inlay will not likely follow. So it is of great importance that the plaster cast be applied snugly to the fractured limb, and cover at least one joint above and one below the fracture.

The inlay graft is more suitable, however, for fracture of one of two parallel bones, where one of the bones is still intact, viz., fracture of the shaft of the tibia, where the fibula is not broken, or in fracture of the radius, where the ulna is still intact, or *vice versâ*.

The open method, or osteoplastic work, should be done if possible immediately after the injury, as a primary reduction and fixation. If it is impossible to do it at this time, it should be delayed until all acute symptoms of traumatism from the fracture or efforts at reduction have subsided.

In case of fresh fracture, as above stated, the bone being normal, the material for the inlay can be taken from the fragments themselves, and used as the material for the graft. This as well as other similar transplant technic would be difficult and laborious without the use of the motor saw.

A very important point to be always borne in mind in osteoplasty (replacing shaft of bone by graft) is, that it matters not how small the graft, it will in time hypertrophy under the action of Wolff's law, and will become the size and strength of the bone it represents, or whose substance it is supplying. The value of the graft in this type of case cannot be overestimated.

In the technic of bone-grafting it is an important point that in all types of fractures the transplant should be of sufficient length to serve the requirements of each and every individual case.

In the case of an intramedullary graft 4″ long, this might afford a great deal of difficulty in its application under certain conditions, but an inlay graft 4″ long can be inlaid as easily as one 2″ long. In a great many cases the success of the transplant depends upon the length of the graft, it matters not whether it is an inlay or an intramedullary dowel. The conditions calling for the application of the intramedullary dowel are much more numerous than those of the inlay. As in almost all acute fractures, the symptom most frequently demanding open treatment is a persistent deformity, or when the broken ends of the bone are unable to be kept in position by external fixation. The above condition demands the application of some internal fixation or means of perfecting the anatomical relations of the fractured ends of the bone or bones. The intramedullary dowel is much superior to the inlay for such purpose. In fact, the bone cannot well be out of alignment or its anatomical relations be other than fairly correct, if the intramedullary dowel is properly applied.

CHAPTER XVII.

Technic Used in Applying the Intramedullary Dowel.

The technic for the application of the intramedullary dowel is as follows: An incision is made over the fracture; the broken ends of the bone are exposed; the blood-clots and other products of the traumatism are removed from and around the seat of fracture, with as little disturbance to the periosteum as possible; the medullary cavity of each fragment is cleaned of that part of the marrow which has been disturbed by traumatism, hemorrhage or inflammation, with a bone curette, and squared with a chisel to the size of the dowel to be used.

The fractured ends of the bone are exposed or approached in the same manner as when the inlay is employed. After bringing the ends of the fractured bones into view, the caliper knives are used to find out the exact size of the intramedullary cavity. The size of the dowel depends upon the size of the medulla. Having decided upon the size of the dowel, a chisel the size of the diameter of the graft is used to square the medullary cavity. If the intramedullary dowel, ½″ in diameter, is to be used, or a piece of bone ½″ rectangular, a ½″ chisel would be used. It is of great importance that a dowel be neither too loose nor too tight; as previously stated, we must have perfect contact of

the graft and the recipient bone. If the graft fits too tight, pressure necrosis is liable to follow; so it is just as important not to have it too tight as not to have it too loose. The great trouble that novices have in the application of the intramedullary dowel is, after the graft has been placed in the distal end of the bone, to place it in the proximal end. This, however, is very easy to accomplish, if the graft fits as it should. Say the graft is 5″ in length, it is introduced into the distal bone fragment from 3″ to 4″. Forcible extension is made on the limb; the protruding end of the dowel is round. The limb is placed in such position that the graft is brought into the most accessible point of entrance into the medulla of the proximal bone fragment; the graft being rectangular, after it once enters, the fragments cannot be rotated on one another, and at once the ends of the bones are brought into a perfect anatomical relation. Half of the dowel is now placed in the approximal end of the fractured bone, by the use of a sharp-pointed instrument. Great care must be taken, as in all plastic bone work, not to allow anything that comes in contact with the skin covering the part operated upon to come in contact with the graft or the ends of the broken bone. The periosteum should be closed with some absorbable material, as plain gut. The soft parts should be brought in contact, layer by layer. Care must be taken not to draw the stitches tight enough to produce pressure necrosis. The skin is closed with plain catgut, subcuticular stitch.

Twenty layers or more of plain gauze are applied over the wound, over which is placed a gauze bandage; we now proceed to apply the external-fixation dressing. Plaster-of-Paris is most commonly used. It must be impressed that the greatest of care must be exercised in the application of the outer dressing, for the slightest false motion will sometimes break the dowel, and absolutely destroy the desired results of the operation.

To repeat, the *more compact the bone-graft,* the better it serves as a transplant. The most available material of such character is found in the tibia or fibula. The transplant must be long enough to extend at least 1″ to 1½″ beyond the irregularities of the line of fracture, or into healthy bone. Its thickness should be sufficient to make bony contact with the entire circumference of the interior of the shaft. The dowel, after introduction, should not bind; it should be loose enough to facilitate its nutrient supply and avoid pressure-necrosis as formerly suggested. It matters not how small nor how large the intramedullary dowel is, the *periosteum* should be *removed always, when and wherever* the graft is *buried in bone.* The periosteum would prevent bone-to-bone contact, which is necessary for the grafting process. All fragments of bone torn loose from the periosteum by the injury at the point of fracture, and lying for considerable length of time in the débris, blood, etc., are dead bone, and are not proper material for transplanting.

For continued success in osteoplasty, the graft

should be autogenous living bone, and placed in its new environment quickly before its supply of nutrition has been exhausted or destroyed. If all conditions are favorable, the transplant becomes transformed into a living integral portion of the repaired bone, serving its part in the functional support of the extremity, and maintaining for a time its shape and size. Later, like any other portion of the skeleton, it becomes modified by the condition, and functional demands upon it. It remains as long as its support is required, after-which the superfluous part is absorbed, and gradually the medullary canal is partially re-established. Should the transplant and recipient bone not have bony contact, fibrous union between them may be expected, and after union of the fracture the transplant becomes absorbed. Should the transplant die because of scanty nutrition, it would become encapsulated and absorbed long after the union of the fracture.

CHAPTER XVIII.

The Bone-peg in Cortical Bone.

The peg transplant in cortical bone, like the inlay and dowel inserts, has its field of usefulness, *i.e.,* fractures of the ends of the long bones, condyles, protuberances, irregular bones, as the os calcis, or, in fact, in fracture of any bone where there is no medullary canal. The fractured area is exposed in the same manner, and the same technic is used as in the application of the intramedullary dowel. In each and every case a peculiar plan is adopted for the application of the bone-graft or peg, that will best retain the fragments in position. The space that the bone peg must bridge is measured, and the size of the graft necessary is estimated. The proper size and length transplant is obtained from above or below fracture or from the tibia or fibula, without periosteum. It must be of one size the entire length, not tapering. The fragments are always first placed in position and the hole bored through them with the same size drill as the peg which is to be used. The points of contact with compact bone are secured wherever possible, for a leverage and center of gravity. The opening through the compact bone must be of sufficient size to allow the transplant to be placed in position without binding. The peg will hold the fragments in position

without being driven tightly. When the fragments and transplant are in position the latter will be in contact with both the cancellous bone on the inside and the compact bone externally, which furnishes a temporary support to the fractured bone, and favorable conditions for grafting.

The part of the transplant which is buried in the cancellous bone stimulates osteogenesis. The growth of new bone spreads from it, and infiltrates the contacting bone, until it merges into a continuous bone-mass, across the line of fracture. This new bone increases in solidity and strength according to the functional demands upon it, taking its part in the support of the body. Later on the graft is modified and absorbed, as the necessity of support is relieved by the bony union between the ends of the fractured bone.

CHAPTER XIX.

Things Essential in Treating Fractures.

A perfect knowledge of anatomy, an accurate observation, combined with simplicity in mechanical methods, will always be recognized as a perfect basis for the treatment of fractures.

The great certainty of the diagnosis gained by the application of the Röntgen rays has suggested more direct and simple methods in the treatment of fractures, and also has contributed much towards an actual interpretation of the physical signs.

The Röntgen rays serve a double purpose, by confirming the diagnosis of the fracture, and also giving much information as to its nature. It is an acknowledged fact that in fracture work the X-ray is indispensable, for the surgeon can see at a glance the relations the ends of the bones bear to each other, and thereby can place the ends of the bones in proper position. Therefore it gives the surgeon the "key" to the real diagnosis and correct treatment.

Every surgeon who is called upon to treat fractures should be provided with a portable X-ray, bandages, splints, plaster-of-Paris, etc. He should not be obliged to gather the material together at the time it is needed. Especially is this true if he treats the patient at his or her home.

The ordinary or simple fracture, as a rule, is a very easy and simple condition to treat.

One of the most important things in the treatment of fractures is the proper adjustment, or placing the ends of the bone in perfect apposition. The next most important step is the application of the splint or dressing, being careful not to have it too tight or too loose, and always using an abundance of surgeon's wadding, placing it the same thickness over the entire surface.

Should the fracture be an oblique one, that cannot be held in apposition (or almost any form of vicious fracture), it is advisable to use the open method.

With the splendid technic and equipment now used by bone surgeons throughout the land, a very interesting field has been opened to surgery in the treatment of a certain class of fractures. The indications for the open treatment in fresh fractures and ununited fractures are entirely different. It is a very evident fact that the large number of practitioners do not appreciate this difference.

In a large percentage of fresh fractures temporary fixation alone is necessary to insure union, as the osteogenetic function of the fragments or fractured ends are active, and in the presence of accurate apposition union occurs rapidly.

In ununited fractures the problem is quite different. We have here in the ends of the fragments a marked diminution or an entire cessation or destruction of the bone-growing elements or

osteogenetic activity. This cessation of activity is evidenced by the marked sclerosis or eburnation which always is in evidence.

The pathology of this condition of sclerosis is very similar to that found in non-ankylosing osteoarthritis, where there is an overdeposit of calcium salts, and a consequent diminution and degeneration of the bone-producing cells.

Abundant evidence has been accumulated to prove that something more than fixation is essential in these conditions, as the most favorable cases of external fixation have failed to unite in spite of months of effectual artificial or external splinting.

It has been suggested, to meet the above therapeutical requirements, that spanning of the fractured area with a very thin autogenous periosteal graft has given a fair percentage of good results, but it is not an ideal procedure in that it does not furnish efficient fixation. It does not stimulate osteogenesis between the ends of the fragments; it is entirely superficial, and does not penetrate cortical bone-structure; therefore it furnishes an imperfect graft environment.

The inlay graft or cortical bone transplant not only affords a fair fixation, but also furnishes the most ideal environment for the bone-grafting; it brings each layer of bone in close apposition with its corresponding layer—periosteum to periosteum, compact bone to compact bone, endosteum to endosteum, etc.

The intramedullary dowel is an excellent

method, which gives almost perfect fixation, and, being entirely osseous, favors stimulation of osteogenesis, when there is good contact of the graft to the recipient fragments.

Bone surgery should not be attempted without perfect equipment. Transplanting of bone should be restricted to wherever the closed method will not give good results, and also in those cases that apparently will be exceedingly delayed in union.

I believe that the operation or open treatment of fractures will find as broad a field for itself in the near future as has the operation for the radical cure of hernia.

In almost all of the textbooks on general surgery advice is given in simple fractures to delay the operation for at least one week; in compound fractures a longer time—two weeks or longer. Advice is also given not to remove blood-clots; the reason given for not removing clots and shreds of tissue is that they act as irritants, and thereby aid in the formation of callus. This is erroneous. You would not leave a blood-clot at the seat of any fracture any more than you would leave it in a wound in the abdomen.

The time to operate in all fractures excepting compound, if operation is decided upon, is the soonest possible moment that you can get the patient prepared. Jones has well said that if a surgeon is doubtful whether he can treat a fracture effectively by non-operative means, he ought to consider whether he can do better by using the open method at once. He should not say "Well,

we can see what will become of it, and if it is not satisfactory we can operate later," for by so doing the only opportunity of getting a good functional result is irretrievably lost.

The necessity of open treatment should be recognized as soon as possible. PRACTICALLY EVERY TYPE OF FRACTURE NEEDS OPERATIVE INTERFERENCE, IF COMPLETE REDUCTION IS OTHERWISE UNFEASIBLE. As previously stated, the X-ray obviates many difficulties in determining this fact.

CHAPTER XX.

The Time to Operate on Fresh Fractures.

The most favorable time for intervention in fractures that cannot be held in apposition by the ordinary methods is at once, after such condition has been discovered, or as soon as the patient can be gotten in suitable surroundings, and properly prepared, and when the condition of the patient will permit. If not within a day or two after the accident you should wait seven to ten days after the fracture occurred, or until all inflammation resulting from trauma has subsided. As previously stated, for compound fractures, in the majority of cases, on account of infection, it is advisable to wait until the wound of the soft parts has entirely healed, after which time good results can be obtained, if the open method is used.

For clinical purposes, simple fractures may be divided into three groups:—

Group 1. Fractures that can be reduced by manipulation, and held in perfect position by external fixation; in such cases the open method is counterindicated. In this very large group of fractures good functional and anatomical results may be, and are, obtained by the external method.

Group 2. Fractures where the fragments cannot be reduced by external manipulation to per-

fect anatomical relations. The fractured ends should be exposed by an incision, and the broken ends of the bone placed in proper position. After reduction has been perfected, if the fractured ends can safely and securely be immobilized by external fixation, internal fixation is not required.

Group 3. Fractures where it is necessary to expose the fractured ends by an incision to bring about a proper reduction, and where it requires internal alignment and both internal and external fixation or immobilization to secure the desired results.

The execution of the technic involved in the application of the bone-graft necessary to assure success, and many of the conditions that I have enumerated, would be difficult, slow, and inaccurate, except for the application of the electric motor and attachments, such as twin saws, drills, burrs, and doweling instruments. These save time, avoid trauma, both to the bone and soft parts, favor precision in modeling the graft and preparing its bed, and simplify and make easy the technic in deep wounds and regions difficult to get at with hand instruments.

Crile says that the motor instruments diminish shock, on account of the lessened excitation of the efferent nerves by the rapid movement, and consequently the minimum disturbance is caused to nerve center.

However, it is evident that the shock formerly experienced in bone work has largely if not entirely disappeared since the development and use of the motor instruments. Whether this is due to the

marked shortening of the time required for operation or to the Crile theory, or both, and in what proportion, it is very difficult to determine.

It cannot be too often mentioned that bone surgery does require a special technic. Vigorous aseptic precautions in preparation of the operative field, the surgeon, and his assistants are absolutely essential.

The fractured ends of the bone should always be exposed by a generous incision. The skin and subcutaneous tissues are retracted. In an ununited fracture, the firm adhesions between the ends of the bone are now easily relieved, or broken up, with the author's elevating spoon or skid (Fig. 48). When released, the ends of the bone are held firmly with the author's bone elevating forceps (Fig. 47). The ends are now developed or freshened with the motor burr or saw, and the sclerosed plug is removed from the medullary canal with the author's special sharp-nose burr. If the dowel is used, should there be an overlapping of the fragments, the amount of pulling necessary to correct it varies with the strength of the patient, and the degree of overlapping. As soon as the extension is sufficient to overcome the overlapping, the ends of the bone are brought in apposition, and we must now decide if we are to use the intramedullary dowel or the inlay.

Should we decide to use the rectangular dowel or peg, we would enlarge the medulla with the motor drill and chisel large enough to receive the graft. All preparations having been previously made, the

graft is now removed from the selected field—from the shaft of the fractured bone, or, if from the tibia, the anterior and inner portion thereof is preferable. Single or parallel motor saws are used to sever the graft from its maternal bed, and it is then grasped with the author's graft-retaining forceps (Fig. 44), and lifted from its mother-bed.

This forceps is made with a rachet, and the graft once in the jaws of the forceps is held firmly until released. This is quite essential, as many a transplant has been dropped, and it is then absolutely worthless thereafter. Not only does this forceps safely hold the graft, but makes easy the placing of it in its future bed. The dowel should fit snugly in both ends of the bone. Before placing the dowel in position, a thorough examination should be again made of the medulla to see that there is no oozing, for a hematoma of considerable size means death to the transplant.

If using the inlay, the fractured ends are held in good alignment by the author's bone clamp (Fig. 49). The periosteum is divided with the caliper knives, longitudinally, over the bone to be removed for the bed of the graft. It is then pushed out of the way of the saws, making a gutter for the bone inserted, for which we would use either the single or twin saws, and we would also use the same saws to cut out the graft or inlay, in some cases using as small a graft as $3/16''$ in width, and in others as large a one as $7/8''$ wide, or even wider.

The exact length of the insert is obtained by measuring the gutter. If the length is correct, the inlay should fit accurately. The transplant can be fastened with bone-pegs or kangaroo tendon, the holes being made through the ends of the bone, and the inlay, with the motor drill.

It is readily seen that this not only affords a fair fixation, but also furnishes the most ideal environment for the bone-graft. It brings each layer of bone into close apposition with its corresponding layer, or in contact with each other.

The periosteal covering of the transplant and the periosteum covering the fractured ends are sewed together with chromic gut; the skin is closed with plain gut, subcuticular; and the wound is covered with plain gauze. A fixed dressing is now applied which is not disturbed for 4 to 6 weeks, unless we have a rise of temperature.

In summing up, the things most important are: (1) careful examination and diagnosis; (2) if simple fracture, bringing the ends of the fractured bone into perfect apposition by manipulation if possible, if not, then use operative means; (3) choosing of the dressing used, splints or plaster-of-Paris; (4) application of dressing, being sure that just the right pressure is used, not too tight or too loose; (5) if the open method is used there must be perfect technic, for unless the technic is perfect good results cannot be obtained; perfect technic is impossible without thorough equipment, and suitable surroundings; (6) careful reparation, with as little trauma as possible, of the

soft parts, ends of the bone, and inlay or dowel; (7) a well-fitting graft which aids osteogenesis, gives perfect fixation, and prevents bleeding or formation of hematome, which would cause death of the graft; (8) in case of an inlay graft, careful preservation of the periosteum, which aids the blood-supply, and the blood-supply to a graft means life, and life means success.

In ununited fractures, or in pseudoarthrosis, of the long bone, where the surgeon anticipates trouble in holding the bone in position, it is then advisable to use the intramedullary dowel. On the other hand, if the bone is easily held in place, the inlay graft is preferable; for, as previously stated, the inlay transplant carries with it greater osteogenetic power than does the intramedullary dowel, because it is applied with the periosteum, compact bone, endosteum, and marrow intact, and that it contacts with tissue of like consistency. Under such environments, the transplant lives and grafts more readily than it does under other conditions.

In either pseudoarthrosis, or ununited fractures, the graft varies in length from 3″ to 7″, governed by the size of the bone fractures and the extent of the impairment of osteogenetic properties, the extent of comminution, the age of the fracture, and the amount of osteoporosis in the fractured ends. If the fracture is of long standing, it is essential to obtain the transplant from above or below the break, or from the tibia. The recipient bone should be prepared first. In fact,

it matters not from what location the graft is removed from the shaft of the injured bone or from any distal bone of the body; the above technic should always be carried out.

Great care should always be taken to protect the graft-bed and surrounding tissues by covering them with gauze wrung out of normal salt solution, while removing the graft from the shaft of the bone, above or below the fracture, or from the tibia, or whatever bone selected. Again, the fact should be emphasized of the great importance of the properly fitting transplant, whether it is inlay or intramedullary dowel. The above is easily accomplished if the operator will use the caliper knives (Fig. 38), setting them at the width desired for cutting through the periosteum covering the bone to be removed for grafting purposes.

It is optional with the surgeon whether he uses the single or twin saws. When the graft and its gutter or bed are formed wholly by the twin saws, the graft is somewhat narrower than the gutter; in fact it is as much narrower as the two furrows cut by the two saws.

For my part, I would much prefer to remove an inlay graft with the single saw, because the inlay should be cut on a bevel; otherwise it could not be made to fit snugly, which is very important.

The intramedullary grafts are preferably removed by the twin or parallel saws, because the width is exactly the same the entire length of the graft when the parallel saws are used. However,

if the surgeon is familiar with such work, he can be almost as accurate with the single saw, in cutting a graft of uniform width, as with the twin saws.

After removing transplants from the tibia, or other bones, unless great precaution is used, fracture of such bone may occur; especially is this true if a considerable portion of the surface is removed. Several röntgenograms were exhibited at a recent meeting of the American Röntgen Ray Society of such cases. A plaster cast should always be applied to the limb to protect it during the entire period of regeneration of bone caused by the removal of the transplant. Adequate support or protection should be continued for at least six weeks; even then the patient should be cautioned in regard to the use of the limb.

From whatever bone the graft is removed for transplantation, it is replaced by a deposit of new bone. The rapidity with which it is re-established depends upon the age and physical condition of the patient, and upon the size of the defect. As a rule, nature readily responds to functional demands for strength. Bone is regenerated in the defect caused by the removal of the transplant, and the remaining bone hypertrophies until the equilibrium between function and strength has been re-established. If the whole segment is removed for transplantation, regeneration is more uncertain. When the epiphyses are undisturbed, and if the periosteum is not too extensively lacerated or bruised, and left in position, there may be

regeneration of the entire shaft of such bone. The regeneration, however, depends largely upon the age and the health of the patient. In the very young and very old, and in debilitated or diseased patients, the regeneration of bone under such conditions, if any at all, is very feeble.

THE RESULT OF INFECTION ON A TRANSPLANT.

The ultimate fate of a transplant in the presence of infection varies with the two following conditions:

1. The time of infection in relation to the transplanting; the final results differ from those in which the transplant is inserted into a bed which has been infected previously, and where the bacteria were introduced into the transplanted bed at the same time that the osteoblastid transplant was inserted.

2. The absence or presence of the periosteum will modify the course of invasion by the bacteria, and likewise the infection of the marrow substance of the transplant. Then the fate of the transplant depends, first, on the virulency of the infection; second, on the time of infection, whether it is primary or secondary; third, on the presence or absence of the periosteum; fourth, on the location of the primary focus.

The permanency of the transplant in the presence of infection is a forcible argument in establishing the viability of the bone-graft. The fact that a bone transplant reacts to an infection is of immense importance clinically. It is demonstrated

biologically, more effectively than histologically, that the viability of the transplant is very striking, and is a permanent osseous entity.

It has been clearly demonstrated that a primary or acute infection of the transplant bed is more destructive to the transplanted osteoplastid than a chronically infected bed; the virulence of the infecting micro-organism is given as the reason. Primary infection, as a rule, terminates in necrosis of the graft, with complete expulsion.

Any portion of a transplant infected may undergo sequestration without affecting the viability of the remaining portion. A transplant infected which has an established sinus does not eventually affect the formation of an excessive callus but rather acts as a stimulus to osteogenesis, with immobilization of the fragments. The periosteum prevents the entrance of bacteria, and prevents the suppurative process from invading the central part of the graft. In mild infection it should be emphasized that the periosteum and endosteum avert bacteria invasion much more readily, and maintain their vitality where compact bone without the periosteum or endosteum would undergo necrotic degeneration and absorption.

CHAPTER XXI.

Special Fractures.

Fractures of the inferior maxillary are far more frequent than those of any other bones of the face. The seat of the fracture will be determined by the force and direction of the blow causing the fracture.

The four most common seats of fracture are the body, the ramus, the alveolar processes, and the articulating processes or condyles. Fractures of this bone do not, as a rule, require operative treatment. Satisfactory alignment can usually be maintained either by interdental splints or by wiring the teeth. The most difficult fracture of the jaw to treat by conservative means is fracture of the ramus, as the interdental splints are incapable of accomplishing the desired results in these cases.

If the fragments cannot be held in satisfactory alignment, after a reasonable effort by conservative means, or should nonunion result, operative procedures should be resorted to.

The inlay graft offers a very efficient and satisfactory agent for the fixation of this group of cases. The graft may be obtained either from the tibia or from a rib, leaving the inner half of the rib intact. The reason that the rib offers such an excellent graft is on account of its contour, or curved condition, which is applicable to

the jaw. The inlay graft is placed in a bed previously prepared in the lower portion of the fragments, enough of the outer surface of the fragments being removed to receive the inlay, so that the outer surface of the inlay will be flush with the outer surface of the fragments.

The bone-graft's most important mission in this type of case is its germ-resisting properties. It is always advisable to wire the teeth in addition to the fixation given by the graft, wiring the teeth of the lower jaw to the corresponding ones of the upper jaw. The same postoperative dressing is required in these cases as if treated by the ordinary method. It is of great importance that the patient keep the mouth as clean as possible, and should be instructed to live on liquid diet until bony union takes place. The wound is closed layer by layer, with absorbable material; the skin is closed by subcuticular stitch, plain catgut being used, over which the usual surgical dressing is applied.

CHAPTER XXII.

Fracture of the Clavicle.

Fracture of the clavicle is one of the most common fractures of the bones of the body. The fracture may be partial or complete, single or multiple, simple or compound. Incomplete fractures occur in children which often escape recognition until a callus has begun to form.

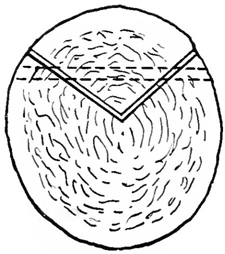


Fig. 63.—Cross-section of clavicle, illustrating the author's method of making use of an inlay graft removed from the fragments of clavicle, and held in position by bone-pegs or Kangaroo tendon. The graft is removed from the anterior and upper portion of clavicle.

About one-half of all the fractures of the clavicle occur in the middle third; a majority of the remaining half occur near the outer end. As a rule, a recent simple fracture of the clavicle can be satisfactorily reduced and held in position by external methods. However, instances do occur where, on account of the obliquity of the fracture, or some other cause, the fractured ends of the

bone cannot be reduced or held in position after being reduced. Under such conditions a thin autogenous dowel or inlay graft should be used (Fig. 63).

The incision is made through the skin ½″ below and parallel with the bone. This position of the incision is chosen because it is not desirable to have the incision directly over the bone, on account of the bone being so superficial, and also because it is not good surgery to place sutures of the skin directly over a bone transplant, so near the surface, on account of possible infection.

The intramedullary dowel is very easily applied if it is not made too long. A peg ¼″ to ⅜″ in thickness, and 1½″ in length, can be easily applied, if a hole 1¾″ deep is made in the end of one of the fragments. The hole must be made with a drill the size of the peg or dowel to be used, in order to easily insert the dowel. A ½″-notch in the opposite fragment must be made, and the center hole should extend ½″ deeper than the notch. The peg is first placed in the fragment with the 1¼″ hole; then the free end of the graft is passed through the notch into the hole in the opposite fragment. The peg is divided equally in the two fragments. Should the outer end of the inner fragment be displaced upward, and the inner fragment be displaced downward, the notch should be on the anterior surface of the clavicle, and not on the upper surface. By placing the transplant in this position, the displacement is absolutely controlled. Should an inlay graft be

used, the transplant can be removed from one end of one of the fragments, and made to fit in the bed made in the opposite fragment, by removal of the same shaped piece of bone but half the length. The inlay should be V-shaped; and the short piece of bone removed from one of the fragments may be used for making pegs to fasten the inlay in position, or placed in the vacancy caused by removal of the inlay.

CHAPTER XXIII.

Fractures of Humerus.

The location and severity of fractures of the humerus, as in all fractures of the other long bones of the body, depend largely upon the amount of force causing such injury, whether it be direct or indirect. The majority of fractures of the humerus can be treated successfully by the external method, excepting, however, if fractures occur near the shoulder or elbow-joint, which should always be treated by the open method. In a certain percentage of fractures of the shaft, in order to obtain the best possible results, operative procedures must be resorted to.

The fractures, then, of the upper end of the humerus most liable to require operative treatment are fractures of the anatomical neck, usually occurring in old people; epiphyseal separation, which occurs in young people; fractures of the surgical neck, which most usually occur in middle life. The above fractures may occur with or without dislocation of the head of the humerus (Figs. 64 and 65).

The prognosis in the above fractures, when treated expectantly, or by the external method, is unfavorable, so far as restoration of complete function of the shoulder is concerned, for in such cases it is almost impossible to get perfect reduc-

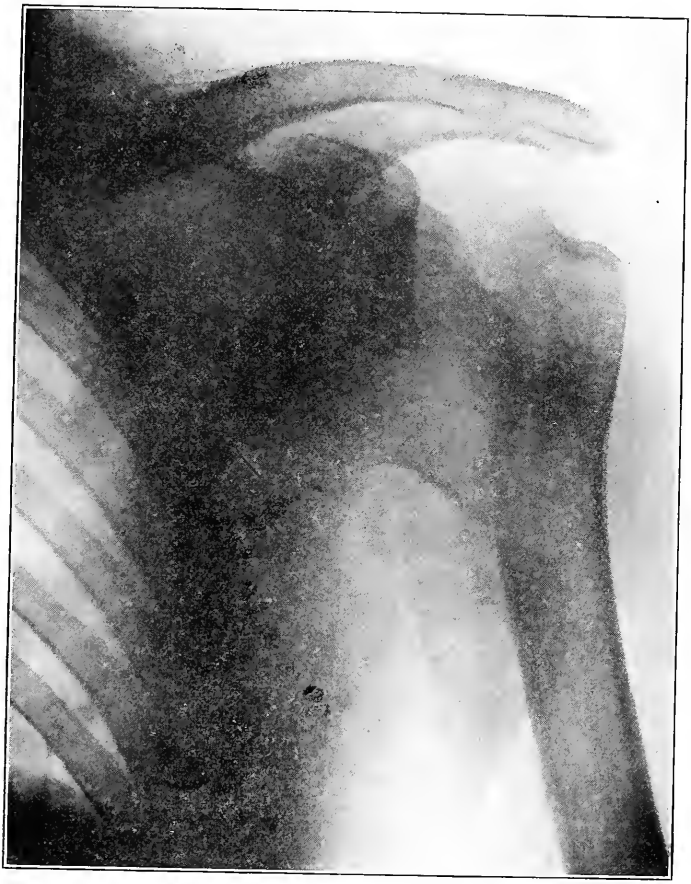


Fig. 64.—Fracture of neck of humerus with considerable deformity. Six months after accident. Impaired motion of arm. (*J. B. Murphy.*)

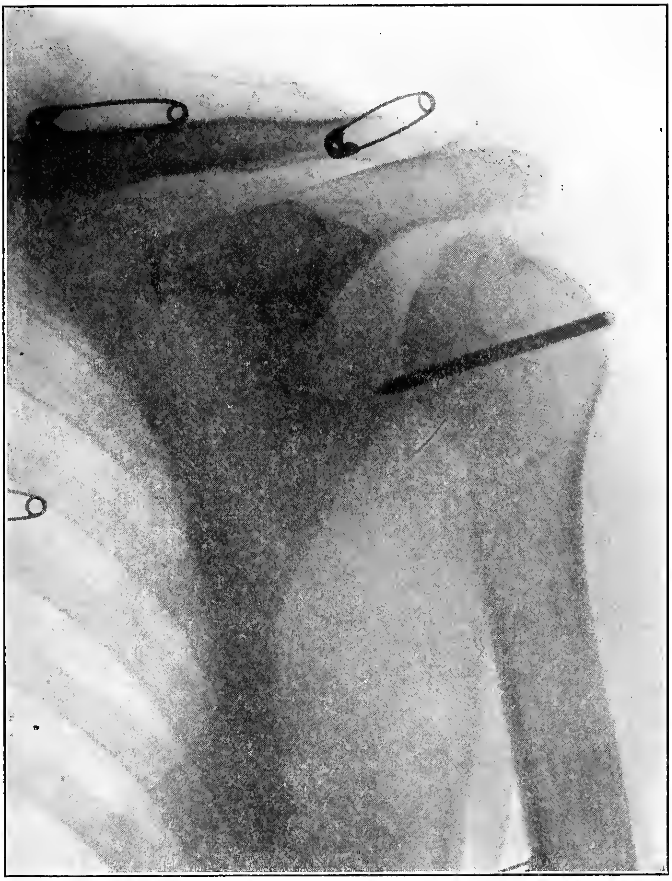


Fig. 65.—Fracture of the neck of humerus, showing 8-penny nail driven through distal fragment into head, with perfect result following. (*J. B. Murphy.*)

tion, especially when complicated with dislocation; and by not procuring perfect reduction and normal anatomical relations, excessive callus formation follows. If conditions permit, the operation for autoplastic repair in all cases should be done immediately after the injury, or as soon thereafter as possible as a primary reduction procedure; if the surroundings and conditions will not permit of

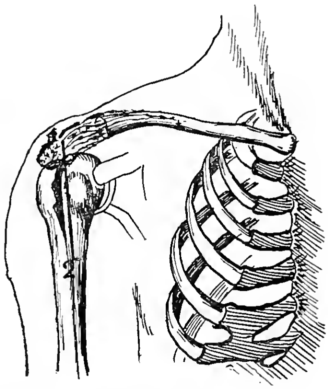


Fig. 66.—Showing Langenbeck's incision, giving the best access to the head of the humerus and shoulder-joint. Used in all operations on the upper end of the humerus down to the insertion of the deltoid muscle.

immediate operation, the operation should be deferred until after the subsidence of all the acute symptoms of traumatism.

The incision that gives the best access to the shoulder-joint or seat of fracture, with the least disturbance to the surrounding tissues, is that of Langenbeck, which is as follows (Fig. 66):

An incision is made from the acromial process, down through the middle of the deltoid muscle to

its insertion, not cutting through the fibers of the muscle, but separating them with a blunt instrument. By carefully retracting the muscle, it gives free access to the fractured fragments. Great caution must be exercised in avoiding the circumflex nerve, as injury to it would destroy some of the movements of the arm by causing paralysis and atrophy of the deltoid muscle.

After the wound has been carefully cleansed of blood-clots, exudates, and detached fragments of bone, the character of the fracture can be easily determined, and the kind, length, and size of the transplant required to support the fragments, and hold them in perfect anatomical relation, decided upon.

The best material for transplantation in these fractures is secured from the shaft of the humerus, from below the fracture, whether an inlay or intramedullary dowel is used (as shown in Fig. 67). The exact measurement of the length and width of the transplant is determined by the use of the author's caliper knives. Great caution must be exercised to prevent injuring the musculospiral nerve. If an intramedullary dowel is used, the periosteum should be removed from the transplant at its source; if the inlay graft is used, the periosteum should always be left on the graft.

The dowel should be rectangular, so that when it fits into the ends of the fragments the corners will impinge and prevent rotation of the head, without rotation of the shaft of the bone; in other

words, it prevents any abnormal motion of the head after the dowel is once placed in position. A

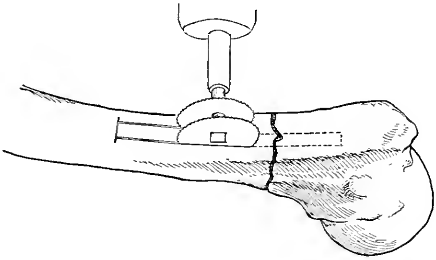


Fig. 67.—Fracture of the surgical neck of the humerus, showing parallel saws being used in removing a sliding inlay graft from distal fragment, making bed in proximal end for its reception.

round spike-transplant would permit rotation between the head and shaft, which would be undesirable (Fig. 68).

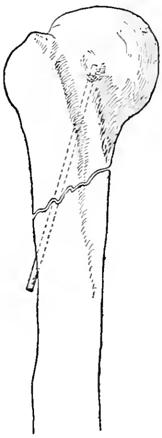


Fig. 68.—Showing the use of the round bone-peg for holding in position an oblique fracture of the surgical neck of the humerus.

After having used the author's $\frac{3}{8}''$ motor drill to make a hole in the lower fragment, $1\frac{1}{2}''$ in depth, or whatever the desired depth may be, if the transplant is to be $\frac{1}{2}''$ square, an ordinary carpenter's chisel $\frac{1}{2}''$ wide would be used to square the hole; then proceed with the upper fragment in the same manner, first using the drill, and after the drill using the chisel to square the hole. While preparing the fragments *the extension must be released.* If the fracture is in the anatomical neck, in squaring the hole you should be careful not to cut through the cartilage covering the head of the bone, but just cut *to* the cartilage. After having prepared the ends of the fragments for the reception of the transplant or dowel, now proceed to remove the graft from whatever location has been decided. The graft is removed, and is now ready for insertion.

As previously stated, if a dowel is used, the periosteum must always be removed. If the ordinary method is used the transplant is first accurately fitted to the lower fragment. It is now removed from the lower fragment, and placed in the upper fragment. In preparing the bed or hole in the upper fragment, great caution must be used to prepare it, so that when the dowel is inserted in the final position in the upper and lower fragments perfect anatomical relation will exist between the shaft and head. The exact rotation-alignment of fragments can be determined either by the irregularities of the fracture or by the known anatomical relations of the head of the humerus to the shaft.

Fig. 69.—Fracture of anatomical head of humerus, showing ordinary displacement of such fracture.

Fig. 70.—Same as Fig. 69, after application of rectangular intramedullary dowel, which holds fragments in perfect anatomical relation, and prevents them from rotating upon each other.

The head of the bone being in correct rotation with the shaft, the transplant is placed snugly into the canal of the lower fragment, after which the free end is placed into the upper fragment or head by the lower fragment being bent at an angle, and extended and manipulated until the free or upper end of the transplant can be made to enter and rest firmly in the squared opening in the upper fragment prepared for its reception.

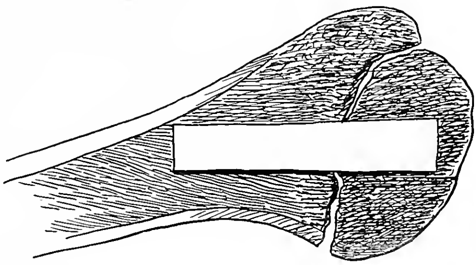


Fig. 71.—Illustrates the use of the rectangular dowel in fracture of the anatomical neck of the humerus.

Before closing the wound, while the repaired fragments are still in full view, the arm is firmly fastened to the side of the chest with adhesive plaster applied to the lower portion of the arm. Before fastening the arm to the chest with adhesive plaster it is well to place between the arm and chest three or four thicknesses of some soft material to prevent excoriation.

The wound is closed, layer by layer, with absorbable material, and dressed with plain gauze. The forearm is placed at about a 45-degree angle with the arm. A crenolin or plaster-of-Paris

dressing is now applied, completely enveloping the shoulder, arm, and forearm. The fixed dressing is removed in four weeks, and passive motion is made of the arm. If the transplant has been accurately applied, with proper attention given to the mechanical condition of the individual fracture, the head of the humerus presenting its normal relations to the joint, the arm completely immobilized during the time required for bony union to take place, the callus formation will be small, and will not interfere with motion of the arm. If the technic has been perfect, early and complete restoration of the function of the shoulder-joint will follow.

Should any of the above details be slighted or poorly executed during the application of the autogenous intramedullary dowel for the repair of this class of fractures, the results will be equal to the efforts made.

All fractures occurring above the insertion of the pectoralis major and the teres major muscles and below the epiphyseal line are considered fractures of the surgical neck of the humerus. After a fair attempt has been made properly to reduce and hold the fragments in proper anatomical alignment and rotation, and such attempt has failed, which frequently does occur, the surgeon is justified in proceeding at once to prepare the patient for open treatment of such fracture.

After careful and thorough preparation of the patient, Langenbeck's incision prolonged downward is used to expose the fracture. After exposing

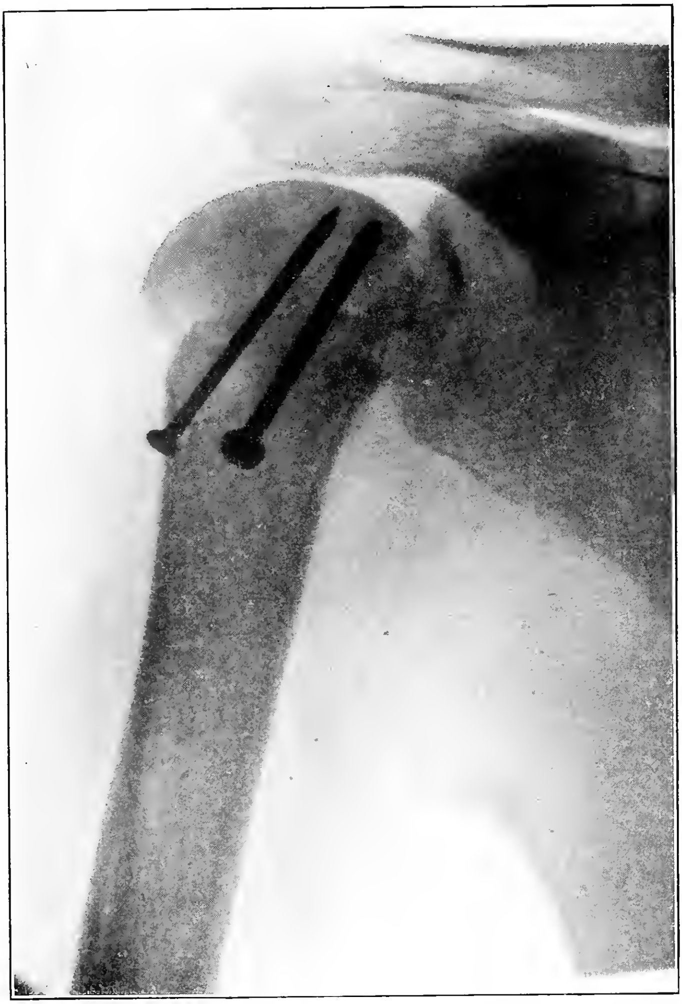


Fig. 72.—Fracture of head of humerus, with two 8-penny fence nails driven through distal fragment into head of bone. A perfect result followed. (*J. B. Murphy.*)

the fractured ends of the bone, the débris caused by the injury is removed from around the fragments. Caution is used to protect the nerves and vessels in close proximity to the fragments during the manipulation of the fractured ends of the bone. The best material for this autogenous transplant is removed from the shaft of the humerus,

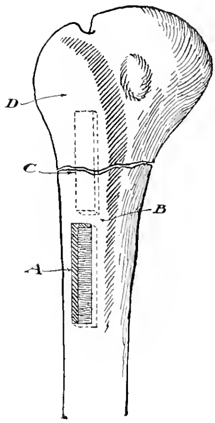


Fig. 73.—Illustrates the author's method of removing graft (*A*) from the distal fragment (*B*) and forcing it down into the medullary cavity, up into position (*C*), dividing the rectangular dowel equally between the fractured ends of the bone (*B* and *D*).

or from whatever bone fractured, 1½″ to 2½″ below or above the fracture, whichever is most feasible. In fracture of the humerus the graft should be about ½″ wide, and 2″ to 3″ in length. After the ends of the fragments have been prepared for the reception of the graft, the graft is forced into the medullary canal, then up through the upper end of the lower fragment into the lower end of the upper fragment (as shown in Fig. 73) or *vice versâ*. If done in the old method the graft is

first fitted into the lower fragment, then removed and fitted into the upper fragment; the lower bed is always made a little bit longer or deeper, so that the graft may be pushed into said fragment, in order to get it into the upper fragment. After engaging in the upper fragment, a sharp instrument is used to equalize the graft between the two fragments. The transplant must not cross the epiphyseal line in a growing bone, as it will interfere with the continuation of the growth of the bone by causing ossification between the epiphyses and diaphysis. The graft in position, if the technic and mechanical details of the operation have been thoroughly executed, the muscles will contract and hold the fragments in normal position and alignment.

The transplant prevents the rotation of one fragment on the other. While the wound is open, and the fractured ends of the bone are still in view of the operator, the arm is securely fastened to the chest by adhesive plaster. The wound is now closed, layer by layer, with some absorbable suture. A subcuticular stitch is used to close the skin, and it is dressed in the usual way.

In fracture of the shaft of the humerus, where we have overriding or a displacement that cannot be reduced by traction and manipulation, open reduction should at once be resorted to. After reducing the fragments to perfect anatomical relations, if the fragments can be held in position without an inlay or intramedullary dowel, it would not be good surgery to proceed to use the

autogenous graft in such case. However, should the surgeon be unable to hold such fracture in

Fig. 74.—*A*, fracture of humerus near middle of lower third, of three months standing, showing considerable callus formation around ends of both fragments, with some bony union between fragments. Bad deformity. *B*, three months after application of intramedullary dowel, with good alignment and bony union.

normal position without the autogenous intramedullary dowel or inlay graft, he should proceed to prepare the fractured ends of the bone for the

reception of the inlay graft or intramedullary dowel (Fig. 75), whichever he thinks best to use The inlay or dowel should be removed from the

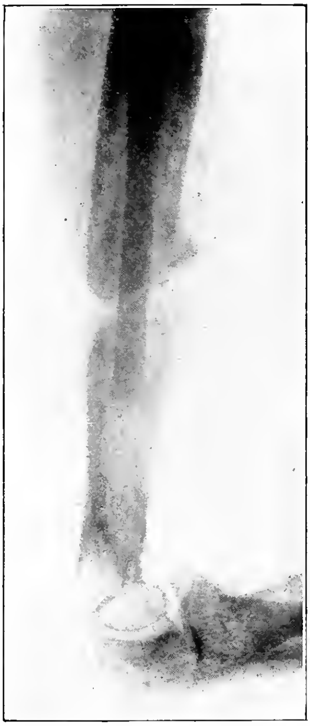


Fig. 75.—Illustrating fracture of humerus after fragments have been placed in position and intramedullary dowel applied. Two months after application of dowel, with fairly good bony union.

shaft of the fractured bone; if not from the fractured bone, it may be taken from the tibia or fibula.

After the fragments have been prepared for the reception of the graft, and the graft has been

removed from the chosen part, the manner of placing it in position would be the same as in fractures of the surgical neck. Any oversized or

A B

Fig. 76.—*A,* fracture of humerus near middle of middle third, showing piece of bone broken entirely loose from both fractured ends of the bone. This fracture could not be successfully treated by the closed method. *B,* two weeks after rectangular intramedullary dowel had been applied, showing loose bone in perfect condition, and fragment ends in perfect anatomical relation and alignment. An ideal result followed.

ill-fitting transplant must not be driven into the medullary canal of any fractured bone, because it will cause pressure-necrosis at the point of forced

contact. The ill-fitting graft may also split the fragment into which it is driven. In case the bone is split by forcing an ill-fitting transplant into its medullary canal or by accidental force, a

Fig. 77.—Transverse fracture of the humerus near junction of the middle with lower third, showing intramedullary dowel in position. Perfect result followed.

kangaroo tendon should be wrapped two or three times around and drawn tightly to bind the fragments together. A loose-fitting transplant is just as bad as one that is too tight. Actual contact of the entire graft to the recipient bone is neces-

sary for continued success. The wound is sutured in the same manner as fractures of the surgical and anatomical neck. In fractures of the shaft, a well-fitting plaster-of-Paris dressing should also be applied; the cast should extend up over the shoulder; the arm should be bound to the body to prevent changes in alignment or any motion between the graft and the host. As a rule, at the end of four weeks the arm should be re-dressed.

Fig. 78.—Fracture of lower end of humerus with deformity. (*J. B. Murphy.*)

The bony union with palpable callus is perceptible, and a straight and good functional arm is the result of a carefully applied autogenous bone-graft. The limb, however, should not be extensively used for at least three or four weeks longer.

In supracondylar fractures of the humerus (Fig. 78), which are in such close proximity to the joints that, unless we have perfect reduction

of the fragments to normal, there is liable to be a callus formation, which in some cases does interfere with the motion of the joint. As a rule, these fractures can be held in position (after

Fig. 78*a*.—Same as Fig. 78, giving a different view. Illustrating fragments held together with an ordinary 8-penny finishing nail driven through proximal ends of distal fragments and distal ends of proximal fragments. (*J. B. Murphy.*)

being properly reduced) by the external method. If, however, the surgeon in charge should not be able to hold the fragments in proper position, the open method should be resorted to.

A free incision is made on the outer surface

of the arm. An intramedullary dowel is introduced in the same manner as in fracture of the shaft of the bone. The closing of the wound and fixed dressing are also used the same as in fractures of the shaft.

In fractures of the internal and external condyles of the humerus, if there is much swelling, it is not an easy task to make a diagnosis without the X-ray. As previously stated, however, the X-ray should be resorted to in all fractures. After completing the diagnosis, and a fair effort having been made to reduce and immobilize the broken condyles, and the condylar fragment is still so displaced that the articulation is abnormal, it is essential that an open reduction and fixation of the fragments in their normal position by a dowel transplant be made at once.

After placing the condyle in position the author's $3/16''$ motor drill is used to make a hole, starting at the most prominent part of the condyle. If it is the inner condyle, the drill should pass upward and outward, passing just above the olecranon fossa and through the compact bone, above and inside of the depression. It is necessary that the peg in such cases should fit very snugly. If the external condyle, the same size drill is used, and the hole is made at the same angle. For the internal condyle, the incision is made directly over the most prominent part, and extends 2″ or 3″ up the arm, which gives good access to the seat of fracture. Care must be exercised not to injure the ulnar nerve.

If the external condyle is fractured, a free incision is made over the outer and most prominent part, and care must be exercised not to injure the tissue in or around the joint. After the application of the autogenous peg, the wound is closed in layers with absorbable material. Gauze is applied to the wound, and the arm is placed in a

Fig. 79.—T-fracture with two 10-penny finishing nails; one driven through external condyle up into shaft, the other through internal condyle, the nails meeting at right angle, into shaft. (*J. B. Murphy.*)

plaster-of-Paris cast, with the forearm flexed at right angle to the arm.

In T-fracture (Fig. 79), or a fracture of both condyles into the elbow-joint, the condyles can be secured by two peg transplants driven into the shaft, one peg anterior to the other, above and below the line of fracture. A plaster-of-Paris dressing is applied, with the forearm at right angle with the arm, after the wound has been closed.

CHAPTER XXIV.

Fractures of the Forearm.

Fractures of the olecranon process are the result of direct violence in a majority of cases. Cases have been recorded that violent contraction

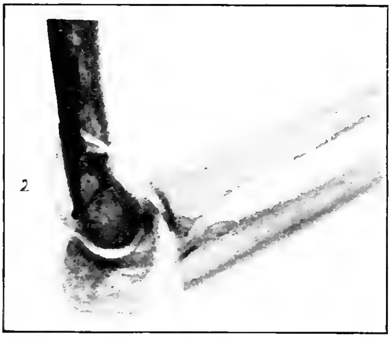


Fig. 80.—Fracture of the olecranon. (*J. B. Murphy.*)

of the triceps muscle has caused such fracture, but it is very uncommon. The line of fracture is usually transverse, and passes through the middle or base of the process. It may be simple or compound. There is always a considerable amount of contusion and swelling of the overlying soft parts, and the joint is filled with blood. In some cases it is almost impossible to make a diagnosis of the fracture without the use of the X-ray, on account of the extensive swelling. The X-ray should be used in all cases,

whether swelling exists or not, because the rays show the exact condition and position of the fragments.

If treated by the external method, fibrous union, as a rule, follows. In the majority of cases it matters not how perfect the apposition of the fragments may be, it is almost impossible

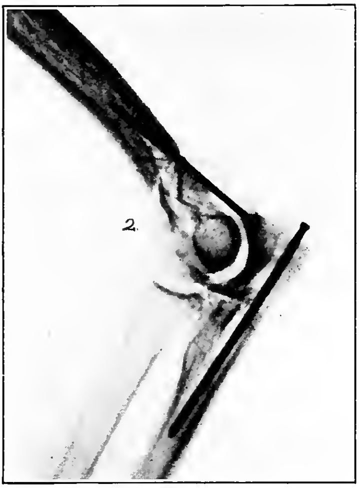


Fig. 81.—Showing 10-penny finishing nail driven through olecranon process into shaft of ulna. (*J. B. Murphy.*)

to get bony union without the use of the autogenous bone-graft; so it is the duty of the surgeon in all fractures of the olecranon process to proceed at once, or at the soonest possible time that the patient can be gotten into the proper condition to be operated upon, to adopt the open method, and apply a well-fitting autogenous bone-graft.

If an inlay graft is used (Fig. 82) the graft can be obtained from the shaft of the ulna, and can be retained in position by kangaroo tendon or bone-peg.

Should it be decided to use an intramedullary dowel, the graft can be removed from the shaft of the ulna or tibia. The graft should be at least $\frac{1}{4}''$ to $\frac{1}{2}''$ in diameter (Fig. 13).

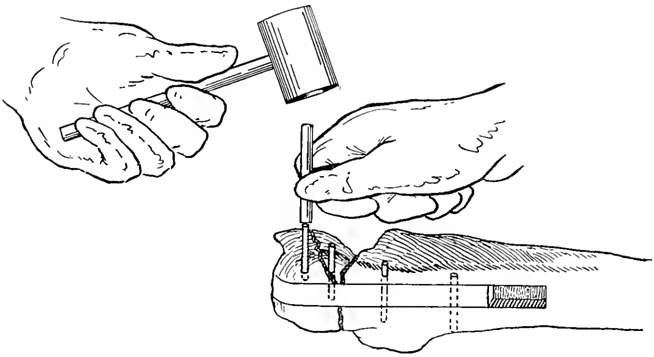


Fig. 82.—Shows the sliding inlay graft removed from the distal fragments of fractured end of olecranon process. Bone-peg made from proximal or short fragment. Also shows method of driving in bone-pegs to hold fragments firmly in position.

In ununited fractures of this process, the bone-graft must extend at least $\frac{3}{4}''$ beyond the eburnated area in the healthy bone. Should the graft not extend beyond the sclerosed area it would fail in its purpose.

Special attention must be paid to the accurate fitting of the graft in this fracture, for the demands upon the graft are distinctly twofold: (1) to stimulate the growth of the bone by the osteo-

genetic properties; (2) to retain the fragments in perfect position.

After closing and dressing the wound in the usual manner, the arm is dressed in the extended position, and a well-fitting plaster-of-Paris dressing is applied, which is allowed to remain on the arm from four to five weeks. On removal of the dressing, passive motion is made. Vigorous use of the arm should not be permitted for six weeks to two months after the accident.

Fracture of the coronoid process, although rarely occurring, is much more frequent than was formerly thought. Fractures of this portion of the upper end of the ulna occur more frequently in connection with backward dislocation of the bones of the forearm at the elbow than otherwise. When complicated with dislocation, there is a tendency for the bone to slip backward again after reduction.

When fracture of the coronoid process occurs as an isolated injury, it is almost always the result of indirect violence, usually from falling upon the outstretched hand.

Diagnosis, as a rule, can be made in these cases without the aid of the X-ray.

Whenever it is impossible to hold the fragment in proper position by the external method, a careful dissection is made, avoiding the blood-vessels and nerves, exposing the fragment, which is placed in position, after which a 3/16″ drill is used to make a hole through the fragment into the bone, the hole pointing forward and downward. A

snugly fitting peg is now driven in, which will hold the fragment in perfect position, and the wound is closed in the usual manner, and covered with sterile gauze. The forearm is flexed at a

A B

Fig. 83.—*A,* fracture of radius, with a space of ½-inch between fragments due to crushing of the bone. *B,* showing intramedullary dowel in position. Two months after operation, with good bony union following.

45° or 50° angle with the arm, and then the arm and forearm are put up in a plaster-of-Paris dressing. The dressing is allowed to remain on from four to six weeks.

Fig. 84.—Fracture of ulna near the junction of the middle with the lower third, with displacement, which as a rule is impossible to reduce by the closed method.

Fractures of the neck of the radius, formerly thought to be rare, are of frequent occurrence. The usual cause is falling upon the hand, with the elbow extended. Fractures of the neck are, as a rule, associated with those of the head, and are frequently impacted. The line of the fracture of the neck usually is transverse or oblique, unless it is a continuation of a fracture of the head. As a rule, perfect anatomical relations can be maintained by the external method. After a fair attempt has been made, and it is found impossible to hold the fragment in position, the surgeon should proceed at once to treat it by the open method using an autogenous peg, extending through the head into the shaft. Should the head be broken, or split in two, a kangaroo tendon of large size is placed a couple of times around the head, and bound tightly, to hold the fragments together. The wound is closed as usual, and the forearm is flexed at a little more than right angle with the arm, midway between pronation and supination, and placed in a plaster-of-Paris dressing. The dressing is removed from four to six weeks after it has been applied, and passive motion is made, with moderate massage.

Fractures of the shaft of the ulna and radius may occur together, or either bone may be broken separately (Fig. 84). The most common seats of fracture are in either the middle or lower third of the long bones. The radius is often fractured a little higher up than the ulna. Fractures of the shaft of the ulna usually occur because of a di-

rect blow received upon the arm, raised for protection. It is not as common as fracture of the radius. Fracture of the radius may occur at any part of the shaft; displacement varies with the location of the fracture.

As a rule, diagnosis of either fracture of the radius or ulna can be made without any difficulty, unless great swelling should exist. Under such conditions, the X-ray should be used before and after attempts of reduction. After a reasonable effort has been made to reduce the fragments to proper relation, without success, the surgeon is justified in proceeding to treat the dissolution of such bone by the open method. If, after exposing the fragments, he finds, as is usual, muscles or other soft tissues have prevented the reduction of the parts to perfect alignment by the external method (manipulation, etc.), and if after placing the ends of the bone in perfect anatomical relation, they will remain so without any further procedure, the wound should be closed and dressed, and treated as a simple fracture. But if the bones will not remain in position, the autogenous bone-graft should be applied, and the inlay graft is well chosen in fractures of the ulna or radius, for all that is necessary in such fractures is to hold the fragments in apposition, which it does to a nicety, except when both bones are broken, then the dowel should be used, for it gives better fixation.

The autogenous graft used in these fractures should be removed from the fragment above or

below the fracture or from the upper third of the tibia shaft, from the upper end of the shaft of the tibia, because the compact bone there is not so thick as in the lower portion of the shaft. The dowel should not be over $3/8''$ in diameter. The same precautions in placing the dowel in these fractures should be carried out as in fractures formerly detailed. The wound is closed with absorbable material, layer by layer, and the skin is closed with plain catgut, subcuticular stitch; twenty-eight to thirty layers of gauze are snugly placed thereon. The forearm is placed at right angle with the arm, and a plaster-of-Paris dressing carefully applied, extending from the finger tips to the shoulder.

Fractures of the lower end of the radius and ulna are quite common. All fractures within 1″ of the articulating surface of the radius are classed as Colles' fractures. The structure of the radius in its entire shaft is quite compact, but as it nears the wrist-joint, about an inch above the lower end, it expands into a more cancellous and less resistant bone-tissue. The articular surface of the radius possesses not only a groove for the ulna, but it articulates with all of the first row of the carpal bones.

Fractures of the lower end of the radius constitute about 10 per cent. of all fractures of the bones of the body. In typical fractures of the lower end of the radius, the line of fracture is from $1/3''$ to $3/4''$ above the articulating surface; usually it is transverse, but it may be oblique, in

an anteroposterior or lateral direction. A fall upon the outstretched and extended hand is the most frequent cause.

In the treatment of Colles' fracture, one should have a clear conception of the usual displacement of the fragments, and the resultant deformity. It is well to remember that impaction of the fragments is usually the greatest obstacle to perfect reduction of the fragments, by the external method. As in all other fractures, the most important task of the surgeon is to correct the deformity by the reduction of the fragments, and having accomplished this, to maintain them in perfect apposition, until firm bony union has taken place. In a great many cases, this is not done in Colles' fractures, and the natural result is that deformity of the injured member follows.

After the surgeon has reduced or supposedly reduced the displaced fragments, a two-position X-ray examination should be made anteroposterior and lateral. If the X-ray shows that the fragments are not in perfect apposition, and they cannot be so placed by the external method, the surgeon should proceed to use the open method of reduction. After the fragments have been placed in perfect anatomical relation, as a rule, it is not necessary to use the autogenous internal splint. All that is necessary is to apply a well-fitting posterior external splint, before the wound has been duly closed. However, should the surgeon deem it wise to use the internal splint, the autogenous peg is ideal; it should be $\frac{1}{4}''$ to $\frac{3}{8}''$ in diameter, and from $1\frac{1}{2}''$ to $2''$ in length.

CHAPTER XXV.

Fractures of the Femur.

Fractures of the hip (Fig. 85), or neck of the femur, occur most frequently in elderly people. It is by far the most disabling of all types of fracture. It ordinarily is associated with a very

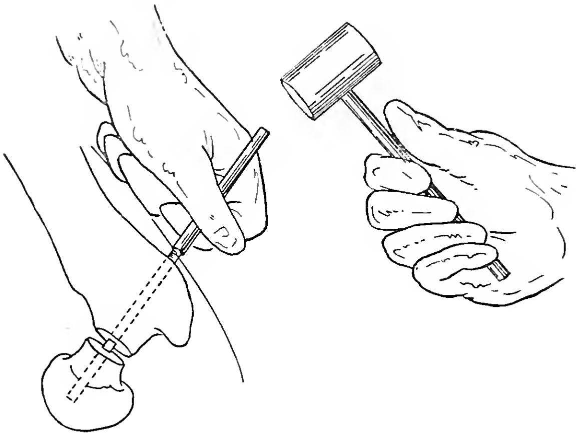


Fig. 85.—Showing rectangular dowel-graft driven in position in fracture of neck of femur, which prevents rotation or motion of head without moving the entire limb.

slight accident, such as a misstep, or fall upon the floor, from a standing position. Undoubtedly, in many instances the fracture precedes the fall. Stimson states that the strain exerted through the ligaments in extreme positions of the limb is a more frequent cause of the fracture than is generally supposed.

Fractures of the femur usually occur beyond the age of 50. They constitute one-third of all the fractures at and after this period of life.

They occur more frequently in women than in men. The chief reason for the frequency of fracture of the neck of the femur in elderly people is the atrophy or osteoporosis which occurs in all parts of the osseous system, and which is more marked at the neck of the femur. The cortex becomes much thinner, and the meshes of the cancellous tissue are greatly enlarged.

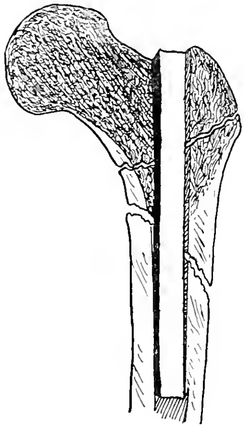


Fig. 86.—Diagram illustrating the rectangular dowel used in fractures of the surgical neck of the femur. By making hole entirely through upper fragment with the author's right-angle arm motor drill, application of the intramedullary dowel is made easy.

There seems to be no object in classifying these fractures any further than the single term, "fracture of the neck," as far as the treatment and prognosis are concerned. However, it might be well to state that nonunion is more likely to occur, and is almost a rule, in fractures of the junction of the head and neck. This is due to the fact that the periosteum of the neck may be extensively torn, as the result of the fracture. If

so, the only source of nutrition for the head is then through the ligamentum teres, and but little, if any, callus formation takes place.

Then, again, this fracture is rarely reduced by the external method, because the small fragment cannot be controlled and rarely held in immobilization for a sufficient length of time for bony union to occur, even if reduction has been completely accomplished. In unimpacted fractures of any portion of the neck, when treated by external method, the prognosis is bad. As a rule, fibrous union takes place, and the functional end results are not good. It is hard to appreciate how unsatisfactory these results are unless careful study is made of various series of statistics. The report of the British Fracture Committee only gives 25 per cent. recovering, good functional results resulting from the conventional method of treatment.

FRACTURE OF THE NECK OF THE FEMUR, AT BEST, IS ONE OF THE MOST DIFFICULT PROBLEMS OF ALL SURGERY. THE SLUGGISH OSTEOGENESIS, POOR BLOOD SUPPLY, DIFFICULTY OF FIXATION, AND THE ANATOMICAL MECHANICAL CONDITION, all are potent adverse influences in securing satisfactory union and good functional results. If radical measures are justifiable in any vicious fracture of the bones of the body, they are indicated in the treatment of this desperate disabling condition.

The late John B. Murphy, who did so much in aiding the advancement of bone surgery, employed

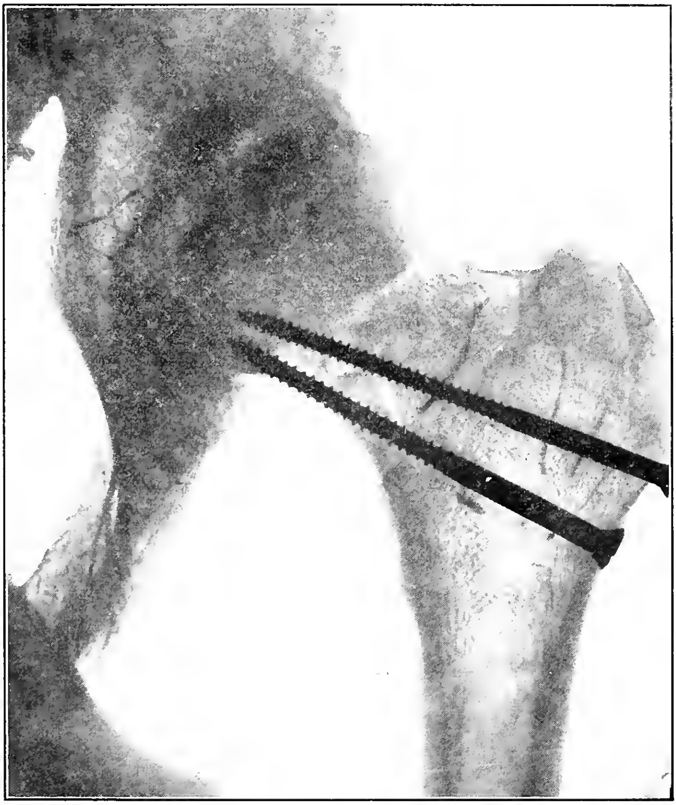


Fig. 87.—Fracture of neck of femur, displaying two screws through greater trochanter, and through neck into head, with bony union resulting. (*J. B. Murphy.*)

the metal spike to secure better approximation and fixation than could possibly have been obtained by non-operative measures. This method, however, has not given good uniform results, because of the bad influence of the metal spike on sufficient callus formation. The disadvantage of the metal spike is overcome by the use of a strong autogenous bone-peg accurately applied to the hole drilled through the neck of the femur. The fragments having been placed in accurate anatomical relation, with a rectangular autogenous bone-peg correctly applied, offers unquestionably the most ideal conditions for rapid and satisfactory union of this most difficult of all fractures.

The influences adverse to union, which are so evident in fractures of the neck of the femur, are better overcome by this procedure than by any other method of treatment. Every argument in favor of the autogenous bone-peg, intramedullary dowel, or inlay graft, in selected fractures and ununited fractures of the shaft of long bones, holds equally good in fractures of the neck of the femur.

The autogenous bone-graft is indicated in most unimpacted fresh fractures, and in all ununited fractures of the neck of the femur, unless physical condition of the patient contraindicates the necessary surgical interference; and in all old fractures of the neck, or at the epiphyseal junction, where malnutrition has resulted, with the neck depressed in a coxa-vara relation to the shaft. In such case, an osteotomy is made, after which a strong autogenous bone-peg is applied.

Fig. 88.—Fracture of the hip in patient aged 65 years.
(*J. B. Murphy.*)

Technic for the operation for the repair of fracture of the neck of the femur by the use of the autogenous bone transplant is outlined as follows:

The patient should be placed upon a traction table, preferably the *Geiger-Murphy,* which will allow simultaneous abduction and traction. The fracture is exposed by an incision starting about an inch below the anterior-superior spine, and extending downward along the inner border of the sartorius muscle. The muscle is encountered and retracted inward. The fragments are now in view, and the débris is cleared away between the fractured ends of the bone. The fragments are freshened by careful curretting.

A second incision is made along the outer aspect of the thigh, over, and just below, the great trochanter, exposing the great trochanter and the shaft of the femur immediately below it. The limb is now placed in abduction, and sufficient traction is applied to bring the fragment into good apposition, aided by manipulation. A line should now be gotten on the direction of the head and neck of the femur. The hole to be made for the graft should be made to pass through the middle and parallel with the neck, appearing at the cartilage of the head of the femur, midway between the insertion of the teres ligament, and the superior junction of the head and neck. The line of the hole can be easily gotten by placing a straight instrument anterior and parallel to both distal and proximal fragments.

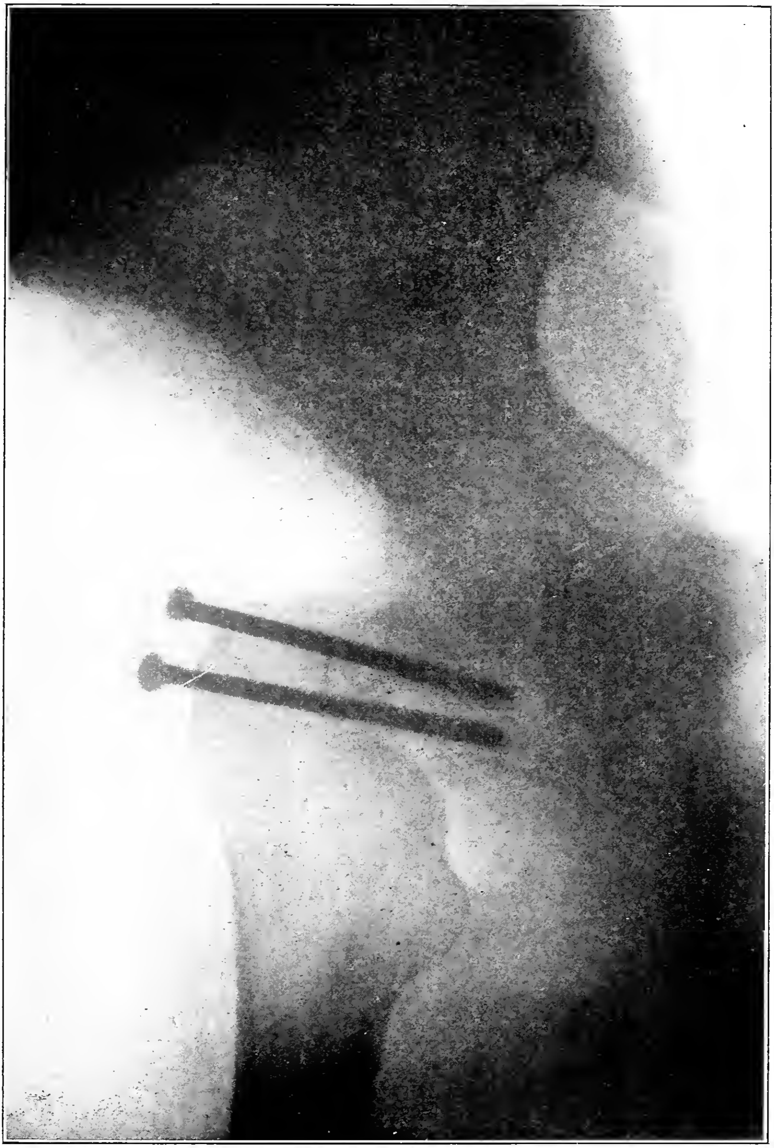


Fig. 89.—Same as Fig. 88, displaying two 12-penny spikes driven through the greater trochanter, and through neck of femur into head. Bony union followed with perfect results. (*J. B. Murphy.*)

The opening is made through the cortex in the outer part of the shaft with the author's electric drill at the level which will give the direction above described. The fragments are held firmly in position while the hole is bored with a $3/8''$ or $1/2''$ drill, after which a chisel is used to square the hole, both in the proximal and distal fragments, which requires little effort, after passing through the compact tissue. The hole or canal extends through the cancellous bone, across the line of fracture to the cartilage of the head of the femur, superior to the attachment of the ligament teres, as above described.

Caution must be used not to pass through the head of the bone and penetrate the hip-joint.

Having the depth and diameter of the canal, a graft is now removed from the lower portion of the shaft of the tibia or fibula. The periosteum is removed from the graft, and left in the position of its original location.

After carefully dissecting back the periosteum, if the graft is to be removed from the tibia, the *Geiger* caliper knives are used to get the exact diameter of the graft by placing the caliper knives in the prepared canal, and setting them, then using the knives to lay out the graft, by drawing the knives down over the exposed surface of the tibia the desired length.

Having laid out the graft, the author's electric saw is now brought into operation. The two sides are cut through very quickly, cutting the graft as nearly a rectangle as possible. The ends are

released now by using the author's $\frac{7}{64}''$ motor drill. Several holes are made across the end of the graft, after which a chisel is used to cut through and relieve the ends of the graft, down to the marrow. The graft is picked up with the author's graft retaining forceps, and is placed in the canal prepared for it.

The graft should fit snugly. The reason that the graft is made rectangular is to prevent rotation of one fragment of bone without rotation of the other. In other words, it absolutely prevents any motion whatsoever between the fractured ends of the bone. The graft once in position, the wound is closed, layer by layer, with absorbable material; the skin is closed with plain gut, subcuticular stitch; gauze dressing is applied as usual.

Marked extension is kept up during the entire operative procedure. The limb is put up in an abducted position (Whitman's position), in a plaster-of-Paris spica, extending from the toes to above the waist-line. Before the plaster is entirely dry, a window is cut in it, large enough to permit dressing the wound. The wound is not dressed, however, for two weeks unless a rise of temperature follows. The original spica is left on for six weeks, and at the end of this time it is removed, and replaced by one extending from the toes to the hip.

In subtrochanteric fractures of the shaft, the diagnosis of such fracture is not usually difficult, as the displacement, as a rule, is characteristic. The upper fragment is flexed and abducted; the lower fragment overrides the upper one, and is slightly adducted.

In a great many cases it is almost impossible to correct the deformity by external means, and if corrected the fragments cannot be continuously held in apposition. In order to obtain a good result in the majority of cases, an open reduction with internal fixation of the fragments in their correct alignment and rotation is very essential.

Access to the fracture is gained by an incision through the outer part of the thigh from the greater trochanter downward over the line of fracture. The upper fragment is grasped and held by the author's bone-retaining clamp (Fig. 49), while the fragment is prepared for the intramedullary dowel. A 3/8″ or 1/2″ electric drill is used first, after which a 3/8″ or 1/2″ chisel is used to square the hole. Should the fracture be within three inches of the upper portion of the greater trochanter, the drill-hole would extend upward, through the cancellous bone, passing entirely through the fragment in line with the intramedullary canal of the femur. The upper end of the lower fragment will be prepared in the same manner.

The transplant is taken from the shaft of the femur, a short distance below the line of fracture, or from the the crest of the tibia from the same limb or extremity, the periosteum being removed from the graft, and left in its original position. The caliper knives are used to get the exact size of the canal prepared, and the dowel is cut accordingly. It is made long enough to pass through the small upper fragment, and to enter the medul-

lary canal of the lower fragment a sufficient distance to give firmness thereto. The wound is closed layer by layer in the usual way, and dressed. The extremity is immobilized by a body plaster-of-Paris cast.

The thigh having been previously abducted and rotated outward to relax the muscles attached to the greater trochanter, and the leg slightly flexed to prevent muscular spasm, spasm probably would cause motion of the transplant, and prevent it grafting to its new bed. The cast is allowed to remain on for four to six weeks, at which time it is removed, and passive motion is given to hip- and knee- joint. Six to eight weeks after the accident the patient may be allowed to begin placing part of the body weight upon the limb.

Fractures of the shaft (Fig. 90), occur most frequently between the ages of 20 and 60 years, and are most common in working people. The causes are direct and indirect violence, and muscular contraction. Fractures of the shaft may be complete or incomplete. Incomplete fractures, however, are rare, but both varieties occur in adults as well as children.

Complete fracture of the shaft may be multiple or comminuted, and those of the middle third are often compound, the fragments penetrating the skin. Injury of the vessels and nerves, although infrequent, must be kept in mind, however, especially in the supracondylar fractures. In the latter variety the lower fragment is pulled back by

the gastrocnemius muscle, and may penetrate or impinge upon the popliteal vessels, and cause gangrene of the vessels, with fatal hemorrhage following; or in case of complete cessation of the circulation, gangrene of the leg.

Fractures near the middle of the shaft are usually oblique. The deformity is due to a persistent overriding of the fragments, which is due to continuous contraction of the muscles. Reduction may possibly be made, but as a rule it cannot be continuously maintained by traction on the leg and by external splints.

The use of the intramedullary dowel is indispensable in fractures of the middle of the shaft of the femur where the fragments cannot be held in position by external means.

The graft may be taken from below or above the fracture of the same bone. The graft taken from such locality is much more kindly received by the host than if procured from a distant part of the body, as previously stated. If, however, it is not feasible, it can be taken from the shaft of the tibia or fibula of the same limb.

To bring the fragments in view, a longitudinal incision is made along the outer border of the thigh at a level that will expose the break. The ends of the fragments are turned out of the wound by bending the thigh. The débris is cleared away. The fragment-ends are prepared, and the diameter and length of the dowel are determined by the use of the author's caliper knives, and the transplant is cut accordingly, without

Fig. 90.—Antero-posterior view of fracture of the femur at a junction of the middle with the lower third, after fixation of the fragments by a sliding inlay-graft from the upper fragment. Also showing bone-pegs giving rigidity and firmness to the graft.

periosteum. The length of the graft is largely governed by the condition of the fractured ends of the bone. If the fracture is transverse, a 3″ transplant is long enough, but should it be an oblique or spiral or comminuted break, the length of the graft is entirely governed by the extent of the splintering, etc., of the ends of the bone. The graft should extend at least an inch or more into healthy bone.

In all cases, the fractured ends of the bone are always prepared before removing the transplant from its original bed, because the transplant should be transferred from the original location to the recipient bone in the shortest possible time, without placing it in any solution, or coming in contact with any liquid, or drying the life fluid, in which it is bathed. The original blood and serum which covers the transplant is always very essential to its life, and should not be removed or disturbed.

If the author's method is not used (see p. 158) and the usual plan is carried out in placing the transplant in position in the fragments in fractures of the femur, the thigh is bent, as previously stated, to give free and unhampered access to the broken ends of the bone. The dowel transplant is first placed in the lower fragment, and, by extension and manipulation, the free end is introduced into the upper fragment. After carefully examining the fracture to see whether the fragments are in perfect apposition, the wound is closed in the usual manner. Great care must be exercised in handling

the limb while placing it in the fixed dressing, which is immobilized in a plaster-of-Paris body-cast; this is allowed to remain for five or six weeks, when it is removed, and the patient allowed to gradually resume the use of the limb.

Supracondyloid fractures, or fractures of the lower end of the shaft of the femur, are usually transverse, and may be treated by the external method. However, should it require an operative procedure, and subjected to open reduction and fixation, the intramedullary dowel should be somewhat larger than when used in the middle of the shaft, as the medullary canal in the lower end of the bone or near the joint is large, and the cancellous bone is softer. The transplant in the lower fragment will require but little fitting. The dowel-transplant may be removed from the shaft of the femur, near the fracture, or from the tibia, or fibulæ, without periosteum. If taken from the shaft near the fracture, the medullary canal is used to pass the transplant through the fragments into the desired position. If the conventional method is used, the transplant is first placed in the upper fragment, and, by manipulation and extension, is placed in the lower one. It is sometimes necessary to make a 1/8″ drill-hole through the lower fragment and the transplant, through which a large kangaroo tendon is placed and tied, to prevent the transplant from passing down too far into the lower fragment. The wound is closed, and the limb is placed in a body plaster-of-Paris cast, and allowed to remain for four to five weeks.

The fractures of the lower end of the femur are intercondyloidal, fractures of either condyle, and separation of the lower epiphysis. In the intercondyloidal variety, the line of fracture is either T- or Y- shaped. The fracture is very likely to be compound, and associated with injuries of the popliteal vessels. The diagnosis is made from the independent mobility of the two condyles on each other by moving them backward and forward, and by the pain when they are pressed together. An effusion into the knee-joint is ever present, and often makes difficult the recognition of the fracture. To make a sure diagnosis, the X-ray should be used.

Separation of the lower epiphysis of the femur is next in frequence to epiphyseal separation of the upper end of the humerus. Usually the epiphysis is displaced forward and the shaft pulled backward by the gastrocnemius muscle. This displacement in many cases endangers the popliteal vessels. The epiphysis may be rotated 90 degrees, so that its joint surface faces the patella when the limb is straight; the same position that you would find when the leg is flexed at right angle with the thigh. An X-ray examination should be made before and after reduction. In fractures of either the outer or inner condyle, the fragments may impinge upon the articulation, endangering the movements of the knee-joint; this condition may recur and exist after the best external reduction that can be made. When this does occur, an incision should be made over the injured con-

dyle, exposing the fracture. After placing the fragments in anatomical relation with the fractured end of the shaft, a drill-hole is passed through it, upward, at the binding angle, through the cancellous bone of the lower end of the femur, and through the compact bone, on the opposite side. A quadrangular transplant is removed from the crest of the tibia, without its periosteum; the transplant should fit snugly, so as to pin the fragment to the femur shaft.

Should both the internal and external condyles be fractured at the same time, two dowel-transplants can be used, the holes being made into the lower end of the femur, so that the transplants or bone-peg will not come in contact with each other, but will cross each other approximately at the middle of the upper third.

The limb is placed in the semiflexed position, and the foot, leg, and thigh are placed in a plaster-of-Paris dressing, and allowed to remain for five or six weeks, after which passive motion is made, and the patient is allowed to begin to bear weight at the end of six or seven weeks.

CHAPTER XXVI.

FRACTURES OF THE PATELLA.

FRACTURES of the patella occur most frequently between the ages of 35 and 50 on account of the activity of people at this age. A thorough knowledge of the anatomical relations of the patella is necessary to have a perfect understanding of the fractures to which this bone is liable. On its upper border the tendon of the quadriceps extensor muscle is attached. On each side of the bone are attached the vastus internus and vastus externus respectively. Below the insertion of the vasti is a portion of the lower attachment of the fascia lata of the thigh.

On the lower border of the patella is attached the patella tendon, the lower end of which is inserted into the tubercle of the tibia, and is separated from the head of the tibia by a bursa, in a pad of fat-tissue. The tendon of the quadriceps, insertion of the vasti muscles, and the patella, are all continuous with the strong fascia lata surrounding the thigh in this region.

The fascia lata is attached posterior and below to the condyles of the femur, the sides of the patella, the tuberosities of the tibia, the head of the fibula, and to the deep fascia of the leg, in the popliteal space.

The patella, therefore, lies in a strong fibrous

sheath that encircles the knee, and which is attached to various bony prominences.

The synovial membrane of the knee-joint lies directly beneath, and attached to the posterior sur-

Fig. 91.—Fracture of the patella, with fragments about two inches apart.

face of the patella. The deep bursa of the patella lies in front of the lower end of the femur, beneath the quadriceps muscle, and often communicates with the knee-joint. When the leg is completely extended, and is at rest, the outline and the anterior surface of the patellæ can be palpated

and moved from side to side. Long striæ of considerable number can be detected on the anterior surface of the patella. In these, tendinous bundles of insertion of the rectus are embedded. It is these fibers that fold between the broken patella

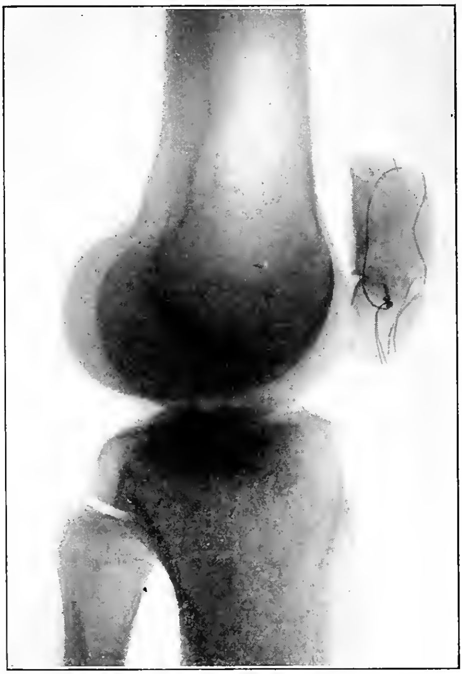


Fig. 92.—Same as Fig. 91. Shows fractured fragments of patella wired together by bronze wire. Bony union resulted with perfect use of membrane. (*J. B. Murphy.*)

fragments and prevent the complete reduction or approximation of the fragments. The patella ligament is parallel with the thigh bone. Eighty per cent. of all fractures of the patella are the result of direct violence, such as a fall or blow upon

the knee. The remainder are due to muscular contraction and indirect violence.

The prognosis as to complete functional restoration without surgical interference in fracture of the patellæ is bad. Bony union occasionally occurs, but it is very rare. It is advisable, then, to operate on all fractures of the patellæ, in order to obtain the best results in all cases. To reach the fragments, a U-shaped flap is made, with the apex of its convexity over the patella ligament, and its base over the condyles of the femur.

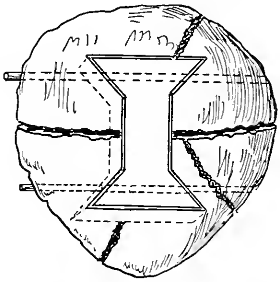


Fig. 93.—Spool-shaped type of inlay-graft usually used in fracture of patella, showing bone-pegs in position holding graft firmly in its bed.

After bringing in view the fragments, all blood-clots and particles of fibrous tissue are cleansed away, and the fragments are adjusted, in case it is a fresh fracture. If it is a refracture, or fibrous union, the fragment ends are thoroughly freshened, after which the fragments are brought in perfect apposition. The periosteum is first removed from the anterior and center portion of the patellæ, splitting the periosteum from above downward, through the center, and turning the flaps

aside. Now the field is ready for laying out the bed or gutter to receive the inlay. The broken patella fragments are brought in close contact. The caliper knives with the scalpel are used in making the design or outline on the anterior surface of the bone. A cylinder-with-flange-at-each-end or spool-shaped outline is made (Fig. 93). With the author's $7/8''$ motor saw, cuts or furrows are made to the depth of $1/3''$, following the outlines previously made. The fractured surfaces of the fragments are now tilted forward, and with a thin, narrow, sharp chisel or osteotome the bone within the previously made saw-cuts is removed to a depth of $1/3''$ to $5/12''$ from the anterior surface of the patella, after placing the fragments in perfect apposition. Again the caliper knives are used to make careful measurements of the bed or inlay-gutter.

The inlay is now taken from the anterior and upper portion of the tibia, where the surface is broad and the cortex thin. The graft must be removed with the periosteal covering. The author, as a rule, uses either a piece of oil linen or sheet-lead which has been sterilized, and cut in the shape of the inlay to be used; this is used as a model in modeling or shaping the bed or gutter, and in outlining the graft. The graft is removed with the author's bone-graft retaining forceps, and placed in position in the gutter or bed. Great care must be taken in removing and placing the graft in position, to produce as little trauma as possible. One-eighth inch drill-holes are now made

through the upper fragment and inlay graft, midway between the free surface of the fragment and the upper end of the graft (Fig. 94). A hole also is made in the same position in the lower fragment; 1/8″ pegs are placed in these two holes, extending entirely through the patella fragments, from side to side. These pegs immobilize and hold the graft in position, while bony union takes place between the graft and the recipient bone.

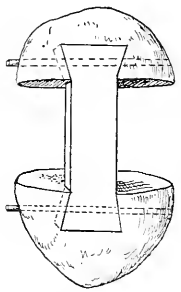


Fig. 94.—Shows inlay graft with enlarged or dilated ends used in fracture of the patella, for bridging across where fragments cannot be brought into apposition. Also illustrates the inlay, held in position by bone-pegs.

The capsule is now sewed together with kangaroo tendon or twenty-day gut.

In stellated fractures of the patella, it may be necessary to use dowels or pegs in place of the inlay; and in certain cases, in addition to the dowel or inlay, it is advisable to use a suture of kangaroo tendon to hold the fragments together more securely, placing the tendon entirely around the patella, laterally through the quadriceps tendon, and the ligament patella, and tying it tightly.

The skin incision is closed subcuticularly with plain gut suture; the limb is placed in a plaster-of-Paris dressing for thirty-five to forty days, at the end of which time it is removed, and passive motion of the knee-joint is made. Within six to eight weeks the patient is permitted to use the limb in a moderate way.

CHAPTER XXVII.

Fractures of the Tibia and Fibula.

Fracture of the shaft of the tibia occurs most frequently from direct violence. Fractures of the tibia and fibula usually occur from indirect violence. The line of fracture is most often oblique, although spiral fractures occur quite often.

The X-ray should be used in all cases in making a diagnosis, for if it is a spiral fracture it is almost impossible to perfectly reduce such fracture, or hold it in apposition after it has been reduced. In the oblique form, the line of fracture runs from below, and anteriorly, backwards and upward; the upper fragment is often displaced forward to such an extent as to lie directly beneath the skin. In some oblique fractures, it is also difficult to hold the fragments in perfect alignment. In all spiral, and in a great many oblique, fractures, it is necessary to resort to the open method. In acute fractures of the shaft, the intramedullary transplant is preferable because it serves the one purpose better than the inlay. The purpose or function of the transplant in fresh fractures of the shaft of the tibia, is to hold the fragments in perfect apposition. When the dowel is properly applied, the broken bone cannot be out of alignment.

To expose the fracture, a curved incision is

made over the shin. If the tibia and fibula are both fractured, at about the same level, reduction is easy. Should the fibula be fractured at a different level, or if the fragments are impacted, reduction, as a rule, is difficult, and in some cases it is necessary to fracture surgically the fibula at a point opposite the break in the tibia. The blood-clots and shreds of fibrous tissue and bone produced by the injury, are cleared from the wound, and the fragments are prepared for the reception of the transplant.

The transplant should be rectangular in shape, so that when it is applied it will act as a key to prevent rotation of the fragments when the broken ends are brought together. The broken ends of the bone are now grasped with the author's bone elevating forceps, and held firmly while they are being prepared.

If a graft 3/8″ in diameter is to be used, a 3/8″ hole of the depth desired is made in each fragment with the author's motor drill. A 3/8″ chisel is then used to square the hole. The peg or dowel should fit snugly. It is first introduced into the lower fragment and is brought into the upper fragment by bending and extending the distal portion of the limb. The dowel in place, and the fragments in perfect anatomical relation, the wound is closed with absorbable material, and dressed with plain gauze. A plaster-of-Paris dressing is applied, beginning at the toes, and extending two-thirds up the thigh, which is allowed to remain for four to five weeks, after which it is

A B

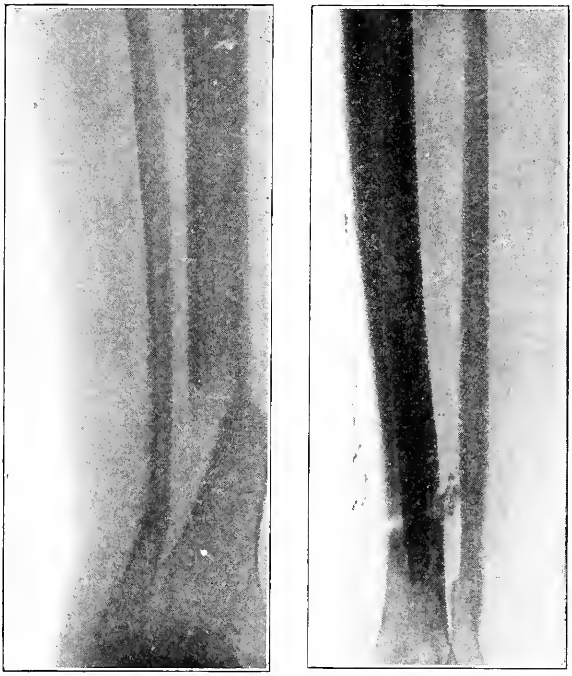


Fig. 95.—*A*, fracture of lower portion of tibia and fibula, with bad deformity. *B*, same as *A*. Taken six weeks after application of intramedullary dowel; with perfect alignment and good bony union of both tibia and fibula.

removed, and the patient gradually allowed to use the limb. Fractures of the lower end of the tibia and fibula are all given the name of "Pott's fracture." They may be either the result of forcible eversion or inversion.

As a rule, diagnosis can easily be made. Where there is a fracture of the internal malleolus, with displacement to such an extent that the mortise of the joint is separated, or where the fragments impinge upon the articulation in a manner which checks free motion, an incision should be made exposing the seat of fracture and the fragments. The malleolus should be fastened to the tibia in its normal relations to the bone and ankle-joint by an autogenous bone-peg or dowel. The peg transplant will mechanically hold the fragment in position, until bony union takes place between the malleoli fragment and the tibia.

The wound is closed as usual, and dressed with plain gauze, and a plaster-of-Paris cast is applied, extending from the toes to the knee, which is allowed to remain for four or five weeks, after which time it is removed, and passive motion is made of the ankle. After five or six weeks the patient is gradually allowed to regain the use of the foot.

CHAPTER XXVIII.

Fractures of the Os Calcis.

Fractures of the os calcis are due to compression in the majority of cases. The patient falls from a height to the ground, striking on his heel. The os calcis is crushed between the astragalus and the ground. Fracture of the os calcis is by far the most common fracture of the bones of the foot.

Fracture of the os calcis may be divided into three general types: type *A,* the fracture confines itself largely to that portion lying behind a vertical line to the middle of the body of the astragalus; type *B* includes all cases of extensive comminution of the anterior half of the os calcis; type *C* includes all cases of extensive comminution of the bone. Abbott states that in such cases the bone is literally "shattered."

Type *A* is the only one of the three to be considered in this connection. In treatment of fractures of the os calcis, the most important point is to reserve or restore the arch of the foot, for the purpose of function, as well as from the cosmetic standpoint.

As previously stated, the X-ray should be used in perfecting the diagnosis of all fractures, and this one is not excepted.

To bring in view the fracture, an incision is made along the outside of the tendo Achillis, down to the edge of the plantar skin, then passing internally around the posterior part of the heel. The flap thus outlined is freed from the posterior end of the os calcis and drawn inward. In loosening the flap, one should keep close to the bone, so the circulation-flap will not be interfered with.

The fragment is now grasped with the author's bone forceps. It may be necessary, in order to loosen the fragment, to force the heel from right to left. In some cases, in order to bring the fragment into position, it is necessary to tenotomize the tendo Achillis, which must be done under strict precautions not to cut anteriorly, but place the tenotome with the cutting edge towards the skin, so as not to harm the blood supply.

The posterior fragment in position, a hole $3/8''$ in diameter is made with the author's motor drill, in line with the axis of the bone (as shown in Fig. 96). The drill-hole should start in the posterior and center portion of the os calcis. The hole should extend at least $1''$ beyond the line of fracture, but it should *not* extend into or beyond the articulation of the os calcis with the astragalus. It is well to leave the drill in position in the hole until the dowel or peg has been prepared. The transplant should be removed from the anterior surface of the tibia of the same leg. With the author's tube saw and lathe attachment, the transplant is converted into the nail or peg

Fig. 96.—Transverse fracture of the os calcis showing a dowel used to hold fragments in position and to stimulate osteogenesis.

with rapidity and ease, without the service of an assistant. The end of the peg must not project out beyond the surface of the os calcis, as it would cause pressure on the skin, and possible necrosis.

CHAPTER XXIX.

Fractures of the Spine.

In fracture-dislocations of the spine, where one or more vertebral bodies are involved, Palmar recommends an immediate laminectomy, exposing thoroughly the spinal cord, followed by an immediate permanent osteoplastic fixation of the vertebra involved with attempt of ankylosis of the two vertebræ above and two below the fractured and misplaced vertebra. After completion of the laminectomy of the one or more vertebræ involved, the incision is extended in both directions. Two spinous processes above and two below the affected vertebræ are exposed. The four healthy spinous processes with their attached ligaments are split *en masse,* with a wide chisel, leaving two-thirds on one side, and one-third on the other. The latter portion is broken over to make a gutter for the transplant. A strong transplant, long enough to overlap the defect and the two vertebræ above and below, is taken from the anterior surface of the tibia, with the author's motor saw, with the periosteum left intact.

The transplant should be V-shaped, and should be placed in the gutter in such position that there will be two bone contacts; the bony contact must be on both sides of the graft. The graft is held in position by $1/8''$ bone-pegs, which are placed in

holes made through the spinous processes of the healthy vertebra and the transplant. The wound is closed in layers, with absorbable sutures; the skin is closed with subcuticular stitch; the wound is dressed with plain gauze, and a body plaster-of-Paris jacket applied, to immobilize the spine, and allowed to remain on for eight weeks. In some cases, it is necessary to cut a window in the cast over the seat of injury, in order to be able to change the dressing.

CHAPTER XXX.

Postoperative Fractures of Tibia.

By removing a segment of the crest or any portion of the tibia opening into the medullary canal, it is weakened out of all proportion to the amount of bone excised, because it interferes with the tubal relations of the cortical bone. During the removal of the transplant, it must be remembered that the tibia is being robbed of its functional bone; that the amount of bone removed must be limited to the least portion that will serve for the transplantation; and that the manner of the removal must conserve the strength of the mutilated tibia. The ruthless methods used in cutting the tibia at the end of the transplant temporarily weaken the bone to the extent of the over-cutting. In place of using the circular saw in freeing the end of the transplant, the author suggests that the $5/64''$ motor drill be used, making the holes across the end of the transplant in close proximity, after which a chisel is used to completely sever the end of the transplant from its bed.

The possibilities of postoperative fractures of the tibia are increased in proportion to the size of the transplant removed, or in proportion to the amount of damage done to the bony cylinder by unskillful and unguarded technic during the removal, and a great number of fractures has oc-

curred to the donor bone on account of carelessness on the part of the surgeon. The removal of the graft for purpose of transplantation is replaced by a deposit of new bone; the rapidity with which it is replaced depends upon the size of the transplant removed, and the age and physical condition of the patient (Murphy). "Responding to functional demands for strength, bone is regenerated in the defect, and bone-hypertrophy takes place, until the equilibrium between the function and strength has been established."

In all cases where a transplant has been removed from the tibia, it should be protected against fracture by a plaster cast during the period of regeneration of the defect caused by the removal.

In removing a portion of the shaft of the fibula for transplantation purposes, where the epiphyses are undisturbed and the periosteum remains, it is more than likely that the entire segment will be regenerated. Especially is this true if it is in a vigorous young person. Age and debility may entirely prevent bone-regeneration. If the patient is young and vigorous, and the entire periosteum remains in a healthy state, as just stated, the whole diaphysis of the long bone may be regenerated.

In case of removal of the fibula for grafting purposes, and failure of regeneration takes place, when a segment of the whole thickness has been removed for transplantation, a compensatory hypertrophy of the tibia will occur to take care of the functions of the bone that was removed.

CHAPTER XXXI.

Delayed Union and Ununited Fractures.

When the usual time required for a fracture to unite has passed, and solid bony union between the fragments has not taken place, delayed union is *now* said to exist. The time is comparative between the physiological repair of fractures, when union becomes delayed, or when delayed union becomes nonunion. After an indefinite time, delayed union may become firmly united, or may result in nonunion. In delayed union it is a rule to find that the callus has covered the ends of the fragments, and united them, but has remained soft, or it has not ossified. The osteoblasts liberated from the fragments by the injury and subsequent changes have failed to do their duty of filling the callus with active, creative elements of new bone, and have failed to stimulate the deposition of calcareous salts in the callus at the proper time. In the presence of these, or under such conditions, the physiological ossification of the callus does not follow. Also the presence of metal or any foreign body, such as a material for fixation, retards osteogenesis between the broken ends, and hinders bony union of the ununited fracture.

The things necessary to produce bony union in ununited fractures are: (1) the removal of the eburnated bone, or the extension of an autogenous

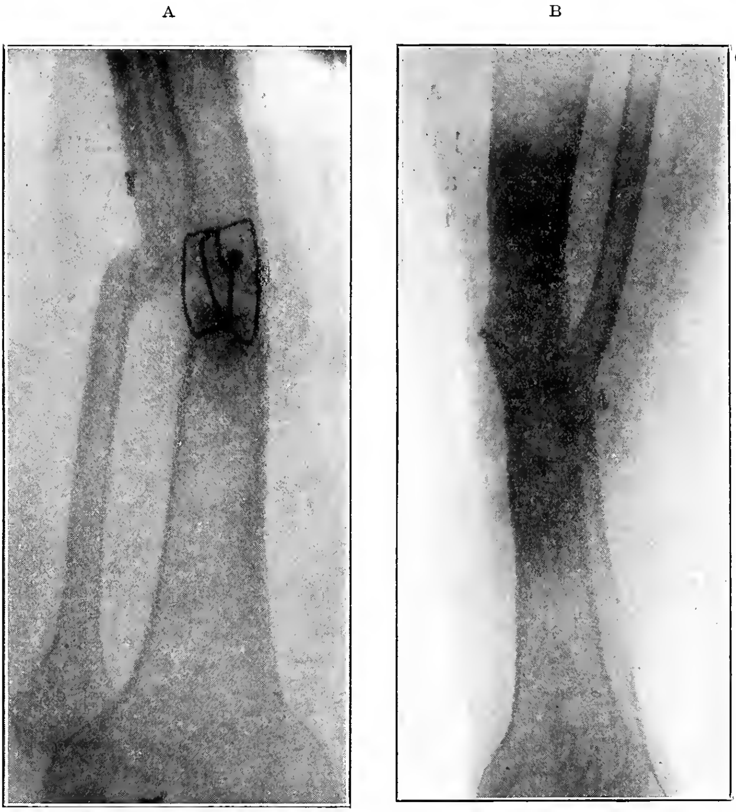


Fig. 97.—*A*, fracture of tibia and fibula, with nonunion after wiring of the tibia. *B*, same as *A*. Two years after operation. An intramedullary dowel was used, but by this time it cannot be seen. A wire nail which is still in position, was also driven through fragments. Head of a small screw was lost in wound; this can be seen on both skiagraphs.

bone-graft far enough into both fragments to contact with healthy bone; (2) fixation of the fragments in perfect alignment, and stimulation of osteogenesis in the area of nonunion, by the application of an autogenous transplant; the transplant grows and stimulates the production of bone-callus in and around the ununited fracture, until normal conditions exist; finally, the part becomes solidified, and the transplant and callus are absorbed as the functional requirements for their presence gradually lessen, and finally cease to exist. The new bone ultimately reaches a permanent basis.

The autogenous transplant in ununited fracture has one special function, viz., stimulation of osteogenesis in the ends of the ununited bone. In ununited fractures, as a rule, after the ends of the bone have been thoroughly prepared, perfect alignment is very easily retained. The inlay graft or cortical transplant is much superior to the intramedullary dowel or peg, as it possesses a superior quantity of stimulating elements in the growth of bone, which is most essential in ununited fractures.

In the delayed union, or ununited fracture, the causes are many and varied, and may be divided into local and general constitutional conditions of the patient. The local causes may be classified as follows: The presence of muscle, fibrous tissue, or tendon between the fractured ends of the bone; imperfect immobilization of the part during repair; impoverished blood supply to the lower fragment, when the fracture is situated near the

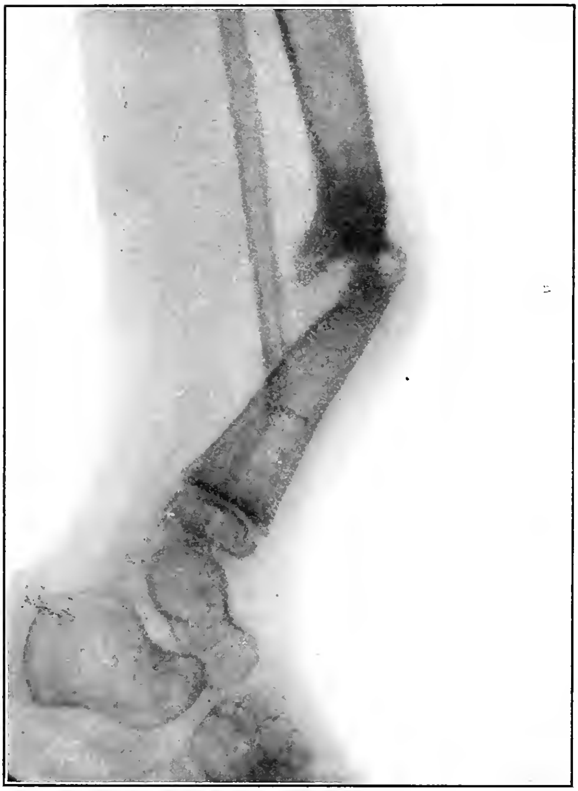


Fig. 98.—Skiagraph of ununited fractures of tibia and fibula in child. Considerable callus thrown out around lower end of upper fragment, with an attempt at union. Lateral view. (*J. B. Murphy.*)

A B

Fig. 99.—*A*, same as Fig. 98. Illustrating intramedullary dowel ten weeks after application. Antero-posterior view. *B*, same as Figs. 98 and 99*A*. Eight months after the application of intramedullary dowel in the tibia. No attention given to fibula. Shows union of both bones. Antero-posterior view. (*J. B. Murphy.*)

nutrient artery; where the nutrient artery is involved; under separation of the fractured surface, either from overlapping or from retraction, as in fractures of the patella; extensive necrosis as is sometimes found in compound fractures, due to extensive trauma of the soft parts, with infection following.

The constitutional causes are specific fevers occurring during the process of repair. If the fever commences about the time of the injury it is especially apt to lead to nonunion. Delirium tremens and the resulting disturbances may deter or even cause nonunion; especially is this true when there are degenerative changes in the kidneys.

In rickets, as a rule, normal ossification does not take place, notwithstanding the abundance of callus thrown out. General debility, anemia, scurvy, gout, old age, and paralysis are said to have some influence upon the repair of fractures or the regeneration of bone.

The direct cause is a diminution or cessation of osteogenetic activity in the ends of the fragments. Unless activity of the bone-growing elements can be re-established, a permanent nonunion will exist. There may be some defective bone disease existing, such as osteomyelitis, or sarcoma.

The efficiency of the intramedullary dowel as an internal splint under certain conditions in the treatment of ununited fractures, or in pseudoarthroses of the long bone, where the surgeon anticipates trouble in holding the bones in position, is far superior to the inlay in holding the frag-

Fig. 100.—Same as Figs. 98 and 99, *A* and *B*. One year after placing of intramedullary dowel in tibia. Perfect union of both bones. (*J. B. Murphy.*)

ments in alignment. On the other hand, if the bone is easily held in place, the inlay graft is preferable, for, as previously stated, the inlay transplant carries with it greater osteogenetic power than does the intramedullary dowel, because it is applied with the periosteum, compact bone, endosteum, and marrow intact, and because it contacts with tissue of like consistency. Under such environments the transplant lives and grafts much more readily than it does under other circumstances.

In either ununited fractures or pseudo-arthroses the length and size of the transplant are governed by the impairment of the osteogenetic power, the extent of comminution, the age of the fracture, the size and length of the bone, and the amount of osteoporosis in the fractured ends.

In order to achieve continued success, the transplant must extend beyond the eburnated area, and at least 1″ into healthy bone in both fragments. The recipient bone or graft-bed should always be prepared first in all cases, whether recent or ununited fracture.

The locations where ununited fractures are most likely to follow are fractures of the neck of the femur, greater trochanter, and lower third of the femur; middle of the shaft of the humerus, patella, bones of the leg, and olecranon process.

In nonunion of fractures of the long bone, a free longitudinal incision is made over the seat of nonunion. The ends of the bones are released from their fibrous union with the author's bone

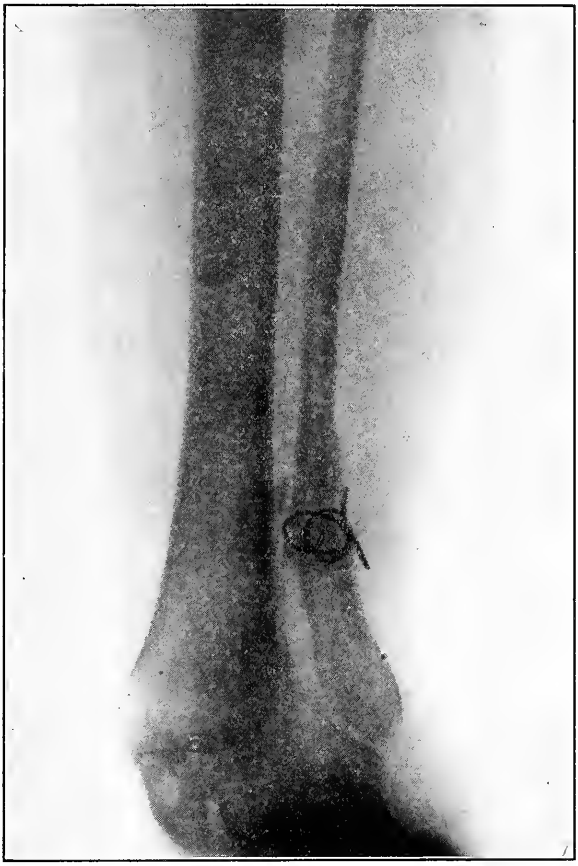


Fig. 101.—Pott's fracture six months after accident, displaying wire used in fastening fracture of fibula, together with bony union between fragments of fibula. Also showing imperfect reduction of articulating surfaces of astragalus and tibia. Result, bad deformity.

Fig. 102.—Upper portion of leg showing almost entire destruction of upper half of tibia, due to acute osteomyelitis, in a boy 10 years of age. Also illustrating an ordinary 6-penny nail driven through the upper portion of fibula into head of tibia.

Fig. 103.—Same as Fig. 102. Shows 12-inch transplant in position three months after application, with perfect bony union resulting, and good alignment of parts. Nail still in position without change in surrounding bone.

elevating spoons or skids (Fig. 48). These instruments are almost indispensable in releasing the fragments of ununited fractures of long standing; with them the fibrous bands are easily broken up, and they greatly lessen the amount of trauma, otherwise unpreventable, which is very essential. After the fragment ends have been released, they are freshened with the author's motor burr. The author's electric single or twin saws are used to prepare the bed for the inlay. If one is not accustomed to using the electric motor single saw in preparing the bed, it is well to use the parallel or twin saws.

The plug of sclerosed bone in the medullary canal of each fragment should always be removed whether inlay or intramedullary dowel is used. The diameter of the inlay is largely governed by the size of the bone, as stated above. In the adult femur, an inlay at least ½″ in diameter, should be used; the length of the inlay depends upon the amount of sclerosis or eburnation. After the bed has been thoroughly prepared, the same twin or parallel saws are used to remove the graft from above or below the injury, or from the shaft of the tibia.

In removing the graft, the ends of the graft are cut through by means of several drill-holes, and finally released by a chisel and hammer. It is not advisable to release the ends of the graft by the use of the circular saw, because of the liability of cutting beyond the side of the graft, which would weaken the donor bone, from which

Fig. 104.—*A,* showing absence of a part of lower portion of tibia, due to osteomyelitis and hypertrophy of the fibula, with marked evidence of Wolff's law. *B,* same as *A,* with intramedullary dowel in position. (*J. B. Murphy.*)

a fracture may follow. The graft is now removed from its original bed by the author's graft-retaining forceps (Fig. 44), and placed in the groove previously prepared. One-eighth-inch holes are now made from side to side through the recipient bone and the graft—two holes in the upper and two in the lower fragment—into which bone-pegs are driven to hold the graft in position.

The wound is closed layer by layer with absorbable sutures; the skin is closed with plain catgut, subcuticular stitch. Plain gauze is applied, and the limb is immobilized by a plaster-of-Paris cast dressing.

If it is a fracture of the neck of the femur the cast should extend from the toes to the axillæ, or at least above the waist-line. Complete immobilization is all-essential in all bone transplantations.

If it is necessary to use the intramedullary dowel, on account of difficulty in holding the fragments in alignment, the method of procedure would be as follows: Place an autogenous bone-graft in the medullary canal of the injured bone, across the nonunion well into each fragment. In such cases, the intramedullary transplant is applicable and gives excellent results. It may also be advisable to use the intramedullary dowel in ununited fractures of the shaft of long single bones, such as the humerus and femur, where it is difficult to hold them in alignment; in parallel bones where both bones are ununited, as the radius and ulna, and the tibia and fibula; where the ends of the fragments are not too badly destroyed by

comminution, scleroses or absorption; where the medullary canal can be cleared of the deposit of hard brittle callus without breaking or destroying the circle of original compact bone of the shaft.

The essentials to the grafting process are: the re-establishment of the medullary canal, in the fragments into healthy marrow, and bone-to-bone apposition of the transplant to the walls of the medullary canal of each fragment, as well as staple immobilization during the necessary time for union.

CHAPTER XXXII.

The Application of the Intramedullary Transplant in Ununited Fractures.

The medullary transplant is applied as follows: The field of operation having been thoroughly prepared, a free incision is made over the nonunion. The ends of the bone are cleared of the interposing fibrous tissue, and freshened with as little destruction of the fragments as possible. The author's electric drill and reamer are used to remove the eburnation and brittle bony formation from the canal of each fragment. Great care should be taken when removing this eburnation not to split or break the brittle ends of the fragments. Should the size of the graft be ½″ in diameter, a ½″ chisel is used to square the hole or canal for the reception of the dowel transplant. The transplant is removed from above or below the fragments, or from the crest of the tibia with the author's parallel or single saws. If the single saw is used, the caliper knives are brought into play, and accurate measurements are made of the canal, and the transplant is laid out on the crest of the tibia with the caliper knives, which will give a dowel the exact size of the canal prepared, if the lines of the caliper knives are accurately followed. It cannot be too forcibly impressed that the transplant must be long enough to reach well

into the healthy bone of each fragment, bridging the entire sclerosed area with fresh living bone. The periosteum must always be removed from the transplant when used as an intramedullary dowel, as it is completely buried, and the periosteum would act as an interposing tissue, preventing bony union between the transplant and its host.

The transplant being introduced into the medullary canal of each fragment, across the defect, and the fragments having been placed in good alignment, the wound is closed in layers with absorbable suture; the skin is closed with subcuticular stitch, plain catgut suture. Complete immobilization is accomplished by the application of a plaster-of-Paris dressing, extending up over the well joint above, and to the joint below, thereby immobilizing both the joints above and below. The cast is allowed to remain from five to six weeks. A window is cut in the cast to allow dressing of the wound; this window is cut before the plaster is thoroughly dry. The wound should be dressed eight to ten days after operation, and as frequently thereafter as may be required.

CHAPTER XXXIII.

CLUB-FOOT.

AUTOPLASTIC remodeling of club-foot must necessarily take into consideration the age of the patient, and the degree and type of the deformity.

In talipes equinovarus the outer side of the foot is convexed, and the surface considerably extended; the removal of a V-shaped piece both from the soft parts and from the os calcis and cuboid bones (as shown in Fig. 105) allows the foot to be straightened and fixed in such position with little effort (Fig. 106).

The technic of the operative treatment, as devised by the author, for dealing with this most common variety of talipes, is as follows:

The deformed foot and lower portion of the leg, having been prepared for operation, the equinos is first corrected by tenotomizing the tendo Achillis to enable the operator to force the foot into dorsal flexion on the leg. A tenotome is thrust through the skin about 1″ above the insertion of the tendo Achillis into the os calcis with the blade parallel, and just anterior to the tendon, the cutting edge of the tenotome is turned posteriorly, and the tendon is divided from before, backwards. Care must be taken to also divide the planteris tendon. The division is very perceptible in the sudden giving away of the resistance to the

dorsal flexion of the foot. A tourniquet is never employed in any kind of bone work, for reasons previously given. A diamond-shaped incision is now made, beginning ½″ in a child and 1″ in an

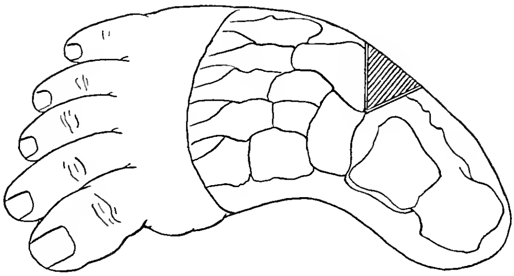


Fig. 105.—Illustrating removal of a wedge-shaped piece taken from the outer and convex surface of the foot in a marked case of talipes equinovarus, including the soft parts; and a wedge-shaped piece from the posterior portion of the cuboid bone; and a wedge-shaped piece from the os calcis. Used in all patients over two years old.

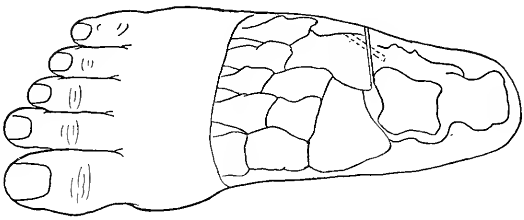


Fig. 106.—Appearance of the foot after a wedge-shaped piece had been removed from the outer surface in an exaggerated case of talipes equinovarus. The foot has been straightened. Also shows dowel in position to give rigidity and firmness to the bones of the foot in their new relations until bony union takes place.

adult, anterior to, and level with, the external condyle; the anterior incision extending forward and downward to the junction outermost of the

cuboid and fifth metatarsal bones, then backward and inward to almost the center of the sole of the foot, laterally. The posterior incision starts in common with anterior, and extends downward and backward, at the junction of the outermost portion of the foot. It should be in line with the external malleolus, or with the shaft of the fibula; then the incision passes anterior and inward, meeting the anterior incision near the middle, laterally, of the sole of the foot. These incisions extend into the bone, posterior to the os calcis, and anterior to the cuboid. The soft tissue is now removed *en masse*. The motor saw is now used to remove a V-shaped piece from the os calcis and cuboid bones, the apex of the V meeting near the junction of the os calcis, scaphoid and cuboid bones. Two slanting holes are now made in the os calcis and cuboid, opposite to each other on the anterior surface, with the $5/64''$ motor drill. Two similar holes are made in the posterior portion of the bones. The sharp edges of the bone are removed from around these holes, so that they will not sever the kangaroo tendon, which is tied tightly around them to hold the bones intact until bony union takes place. The connective tissue is brought together by a continuous chromic catgut suture, which, in addition to the kangaroo tendon, assures continued contact of the new surface of the os calcis and cuboid bones. The skin is closed with a plain catgut subcuticular stitch. The wound is dressed with gauze; the foot and leg are placed in a plaster-of-Paris fixation-dressing, which is al-

lowed to slightly overcorrect the deformity, and to remain for six weeks. This operation assures against the recurrence of deformity, gives a good shaped foot, removes the bulky mass of skin and connective tissue which naturally forms on the outer surface of the foot when the deformity is straightened by other methods.

CHAPTER XXXIV.

SPINA BIFIDA.

THE osteoplastic transplant is used successfully in closing the defects in spina bifida and in other congenital defects and deformities of the various bones of the body. Several cases have been reported in which the reoccurrence of spina bifida, or of the spinal hernia, was continuously controlled. The operation should be performed during the first or second year of the child's life, or, in other words, as soon as the child can stand such operation.

For operation the patient is placed in the ventral position, to prevent sudden drainage of the cerebrospinal fluid from the brain on puncture of the sac. The head is placed lower than the buttocks; the body reclined at an angle of 35°. The sac is exposed by a curved transverse incision above the tumor; the tumor is separated from the surrounding tissues, down to the defect in the bone; it is punctured and allowed to gradually subside or collapse, and the sac is then replaced within the cleft. The periosteum is dissected back from the edge of the cleft; the bone is freshened, and is now ready for the reception of the transplant. The caliper knives are used in measuring the opening, and for shaping the transplant, which

may be obtained from the scapula, the upper portion of the tibia, or ribs of the child.

In removing the transplant, an extra amount of periosteum should remain on the graft, so that the transplant may be easily fastened in position by sewing the free edge of the periosteum to the surrounding tissue. The wound is closed as usual, and dressed with plain gauze, fastened snugly to the part with oxide of zinc adhesive plaster.

CHAPTER XXXV.

Autogenous Bone-grafts Used in Replacing Shafts and Articulating Bone Removed on Account of Mutilation and Disease.

In defects of long bones (Fig. 109), where the articulating surface is involved, and a portion of the shaft has been destroyed or removed on account of mutilating injuries, osteomyelitis or osteosarcoma, or a portion of the shaft and epiphyses resected, osteoplastic repair for deficiencies or defects is beyond the experimental stage. Cases in which the entire shaft and one of the articulating ends of the bone have been removed, on account of disease or injury, have been successfully replaced by the transplantation of bone removed from the tibia or fibula. The shoulder being an enarthrodial joint with a large, loose capsule, offers the most favorable opportunity for joint-repair.

The defect is exposed by Langenbeck's incision. The fragment end of the humerus is prepared for the reception of the transplant. Should the graft be removed from the upper part of the fibula, the end that is placed in the medullary canal of the humerus is stripped of its periosteum. The upper free end is inserted into the glenoid cavity, and the capsule of the joint sutured around it. The

Fig. 107.—Upper half of humerus enlarged, enlargement gradually diminishing to normal size, with a peculiar exostosis springing from near the head. Female, aged 15; diagnosis, malignant.

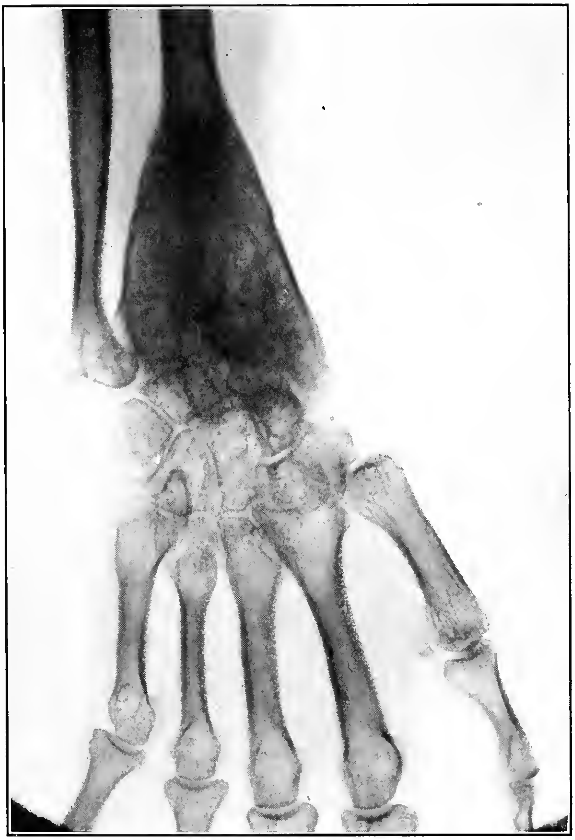


Fig. 108.—Case of osteitis fibrosa cystica of the lower articulating surface of the radius, in girl 11 years of age. (*J. B. Murphy.*)

Fig. 109.—Osteitis fibrosa cystica involving upper extremity of femur for about one-third distance. The articulating surface and head appear to be intact. (*J. B. Murphy.*)

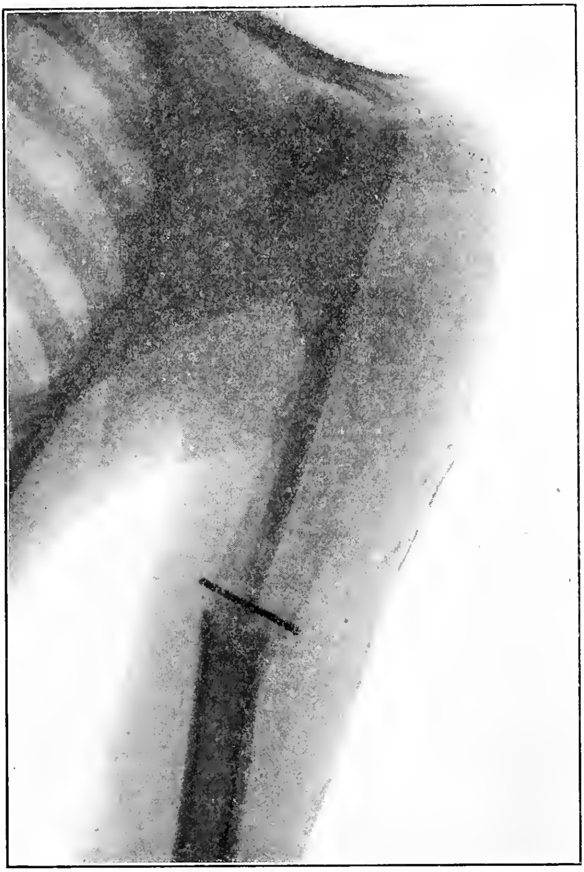


Fig. 110.—Same as Fig. 109. After removal of diseased bone, including articulating surface. A transplant 7½ inches long was removed from the opposite tibia; the lower end was driven into the medullary canal of the humerus fragment, and held in place with a small wire nail. The upper end of the transplant was placed in the glenoid cavity, and the capsule sutured around it. (*J. B. Murphy.*)

Fig. 111.—Same as Fig. 109. Nine months after operation. The upper end of the humerus has been regenerated to a considerable extent, including the tuberosities and the articulating surface. The white line a little to the right of the central axis of the new portion of the shaft represents the periosteum, which was left on the transplant. (*J. B. Murphy.*)

muscular attachments and muscles are sutured in place, and the wound is closed in layers; the skin is closed with subcuticular stitch.

In a case reported by the late Dr. John B. Murphy (Figs. 109 and 110), resection of the upper part of the humerus, including the epiphyses was performed for osteitis fibrosa cystica in a girl 10 years old. A transplant from the crest of the tibia $7\frac{1}{2}''$ long, $\frac{3}{4}''$ wide, and $\frac{1}{2}''$ thick, was removed, and transplanted into the defect. The end of the graft that was driven into the upper end of the fragment of the shaft was denuded of its periosteum, and the upper end of the graft was inserted in the glenoid cavity, and the capsule of the joint sutured around it. The wound is closed as usual, and the arm dressed in abduction at right angle with the body, with weight extension. At the end of five weeks the transplant had grafted to the humerus; there was good motion at the shoulder-joint up to right angle (Fig. 111) in abduction. The inferior epiphyses of the ulna, with its articulating surface, and a portion of the shaft, were resected by Dr. Bloodgood, on account of osteosarcoma, and were replaced by a transplant removed from the ulna above the resection. The patient recovered in three months, with a good motion of the wrist-joint.

CHAPTER XXXVI.

Remodeling or Repairing the Nose.

Remodeling of the bridge of the nose with osteoplastic transplantation to remedy the deformity produced by destruction of the bony framework, by injury or disease, has been employed with success by Drs. Lothrop, Carter and others. In the method of operation used by Lothrop, the bone-transplantation is obtained from the vertebral border of the scapula. It furnishes a transplant already shaped, except in length and width, which are obtained by the use of the caliper knives; it is covered with periosteum on both sides and top; it is much more likely, when grafted in position, to retain its vitality and shape in its new relations without becoming absorbed, or overgrowing, than grafts received from other bones of the body.

Lothrop makes an incision in the under surface of the tip of the nose, and a subcutaneous canal extending up to the nasal bone. The periosteum on the nasal bone is elevated, along the bridge of the nose, to the frontal bone. The nasal bone is dressed down until the transplant fits. The scapula graft is then fitted to the length, and placed with the fresh-cut surface next to the nasal bone. It is placed into the canal prepared for it beneath the periosteum, and is forced in until the frontal

bone is reached. A dressing is applied to the nose whereby a slight amount of pressure is made upon the transplant to hold it in apposition with the frontal bone. This dressing should be removed at intervals, whenever soiled. At the end of four weeks the transplant should be grafted to the nasal bone. Great care should be exerted during the above time to avoid any cause of motion of the transplant.

In defects of the skull various methods have been devised for their correction. Dr. Ropke has suggested that a graft be removed from the wing of the scapula, as it affords an excellent graft for such purpose, because of its thinness, and also that it is covered on both sides with periosteum.

The technic used for inserting bone-grafts for skull defects is as follows: After shaving and thoroughly preparing the scalp, an oval incision is made at least half an inch larger on all sides than the opening in the skull. In separating the scalp and the dura great caution must be used. In case the dura is thickened and adhered to the brain proper, it should be dissected away, providing the adhesions have produced brain symptoms. A flat piece of steel is now placed between the skull and dura, to protect the underlying brain, and a sharp chisel or osteotome is used to freshen the edges, and to cut away the thin ring back to the normal thickness of the skull, and shape the opening ready for the reception of the graft. The edges are bevelled to prevent the graft from causing undue pressure on the brain. The dimensions

of the opening are now carefully taken with the caliper knives, and a pattern is made of oil paper or sheet-lead to fit the opening of the skull. By the aid of the pattern and caliper knives the exact size and contour of the graft is outlined on the surface of the periosteum. The graft is removed with the author's $3/4''$ motor saw from the wing of the scapula, or from the upper and anterior portion of the shaft of the tibia. The edges of the graft should be bevelled the same as the edges of the bone in the opening of the skull. An abundance of periosteum should be removed with the graft. In preparing the bed for the graft, should the dura be lacerated, a thin sheet of collodium should be applied just before the transplant is put in place. A few stitches of No. 1 chromic gut are used to sew together the periosteum of the graft and skull, and the scalp is closed in the usual manner with plain gut. A plain gauze dressing is snugly applied, and retained in position with adhesive plaster.

CHAPTER XXXVII.

Tuberculosis of the Vertebræ.

Synonyms for this disease are: Pott's Disease, Spondylitis, Caries of the Spine, Hump-back, Angular Curvature of the Spine, and Kyphosis.

The name Pott's disease is given to a tuberculous infection of the vertebra, attacking in most cases the bodies of the vertebræ, rarely the spinous processes or the laminæ. It derives its name from an English surgeon, Percival Pott, by whom it was first described in 1776. It occurs oftener in the male than it does in the female, and is one of the most common tubercular infections of bone.

The location most commonly affected is the lower portion of the dorsal, or upper portion of the lumbar regions. However, it may occur in any part of the spinal column.

The etiology of tuberculosis of the spine is the susceptibility or predisposition of the individual suffering with such disease, for the tubercular bacilli are omnipresent in the body, and the only reason that all human beings do not suffer from tuberculosis is that they are not susceptible, or that the soil is not fertile for its development.

Tuberculosis of the vertebra, as a rule, is secondary to a tubercular focus from some other part of the body, such as bronchial or mesenteric

lymph nodes, etc. The tubercular bacillus having obtained access to the body of the vertebra, which is composed of spongy consistency, causes the formation of miliary tubercules. The tubercules enlarge, become caseous in the center, and, by fusion of the caseous area, an area of softening of considerable size is produced. The destruction continues until the entire body of the vertebra is destroyed, after which it spreads to other vertebra, unless prevented by fixation.

It is primarily a disease of middle childhood, but it may occur at any age. About 62 per cent. of all cases occur before the age of 16, only 11 per cent. occurring after the age of 25.

The pathological changes that occur take place as a rule in the spongy tissues of one or more of the vertebral bodies, usually at the anterior portion, and more generally near the articular cartilage than elsewhere, which is termed spondylitis-superficialis, or, more commonly speaking, a superficial infection of the front of the vertebral column. The lamina and spinal processes are rarely attacked; however, this occasionally occurs.

The vertebral column is a weight-bearing structure, and the softening of the vertebral body is apt to result in a collapse of the framework, or column, due to the superincumbent weight. This causes the upper portion of the column to fall forward and form a more or less sharp backward projection, depending upon the number of vertebræ diseased. The deformity is known as the "kyphosis." A multiple focus of infection rarely oc-

curs. By the weight of the body pressing upon the diseased and softened vertebra after the deformity has taken place, the leverage and pressure which contributes to the cause of destruction and deformity continually increase unless such pressure is relieved.

In repair, newly formed bone takes the place of the tubercular-degenerated bone, and ankylosis by granular formation follows. The deformity of the chest and prominences of the sternum are the results of the upper part of the vertebral column falling forward. In severe cases the lower ribs come below the crest of the ilium; a change in the relation of viscera, of the thorax and abdomen, with distortion of the aorta, are caused by the changes in the shape of the chest. The products of the softening caused by the tuberculous degeneration occasionally find their way out under the vertebral fascia into the surrounding tissues. They accumulate back of the pharynx in the cervical region, forming a retropharyngeal tubercular cyst. The word "abscess" is incorrect, unless we have a mixed infection, as we do not find pus cells in a purely tubercular fluid. In the upper dorsal region, they occur most often in the media sternum, or pass between the ribs, finding their way around, and appearing anterior to the sternum, rarely appearing in the back as a dorsal cyst. In the lower dorsal or lumbar region they follow down the course of the psoas muscle, appearing in the groin, or Scarpa's triangle, as a psoas cyst; or in some cases they turn around

the rector spinæ and quadratus lumborum muscles, and appear in the loins as a lumbar cyst.

In a certain percentage of untreated cases the meninges of the cord become involved by extension of the disease; especially does the disease extend to the posterior part of the vertebral body. The inflammation results in thickening, and possibly pressure on the cord. As another cause, we must mention embolism of the spinal vessels. Strangulation of the cord by direct pressure by the bone of the vertebral arch, or loosened pieces of bone, may also cause paralysis. Should meningitis occur, and subside, it leaves behind it a certain amount of sclerosis. Both descending and ascending degeneration may follow.

With the early symptoms come fatigue, loss of flesh, and impairment of the general health. Such children begin to support themselves by leaning against any available object. They have a peculiar gait, and suffer with paroxysmal abdominal pains. The stiffness of the spine, which is found early in these cases, causes a peculiar attitude and walk; the careful manner in which the patient places his foot while walking to prevent jarring, and rises from a chair with the spine held stiff; in all movements, unconsciously protects the spine by contracting the muscle controlling it. Should the patient attempt to pick up anything from the ground or floor, the spine is not flexed as is normally the case, but the hips and knees are bent, allowing the body to be lowered, while the spine is held erect.

In tuberculosis of the spine we may have both anteroposterior and lateral displacement. The deformity of the spine and the attitude of the patient varies according to the region of the spine affected. Pain is rarely entirely absent, and is referred, as a rule, to other joints or parts of the body, or the peripheral ends of the nerves are involved. Abdominal pain is one of the most frequent symptoms in Pott's disease, and is the most common cause of a mistaken diagnosis. Reflected pain in any region or part is increased by accidental jar. In the acute stage we may have a high temperature. In advanced cases of Pott's disease the most characteristic symptom is deformity, caused by the collapse of one or more vertebræ, resulting in a backward or displacement projection of the spinous processes. The deformity in the acute stage of the disease is generally sharp and angular, but later in the disease it becomes more marked and round in character. In the dorsal region the deformity is most conspicuous on account of the normal backward convexity of the spine at that point, and is least noticeable in the cervical and lumbar regions, on account of the forward curves of the vertebra at these points.

If the patient is a child, its clothes should be entirely removed; if an adult, the entire back should be exposed. The patient should then be placed upon the table, or upon the floor, and not on a soft bed, for examination. A close observation of the patient's motion on rising and sitting down should be made. Stopping and turning the head,

stiffness in the muscles of the back or in the neck, on motion, should be regarded as a prominent symptom. In the lower two-thirds of the column the most common symptom relating to this disease is observed by having the patient lie on his face and passively hyperextending the spine while lifting the leg from the floor or table. If the region diseased is the one affected by the motion, the muscles will stand out like whipcord and check the hyperextension.

In cervical Pott's, the motion of the head should be carefully observed; any restriction of motion is suspicious. Any backward deformity establishes the fact that we are dealing with a destructive disease of the vertebra, Pott's disease being the most frequent. If the disease is allowed to continue, we will have a rise of temperature at night; later on, a tubercular cyst in a characteristic situation, and possibly the existence of motor paralysis affecting the parts below the disease, with increased reflex, all of which strengthen the establishment of diagnosis.

After one or more vertebræ have been destroyed, an X-ray photograph should be taken, which will show the destruction of such vertebræ. In earlier cases a negative X-ray cannot be accepted as positive evidence that the disease does not exist.

The prognosis depends largely upon the early recognition of the disease, and the kind of treatment used, and is favorable with the following elements existing: the absence of tuberculous dis-

ease of the joints, good inheritance, fairly good general health, the absence of fever, and without excessive pain at the onset. The reverse elements are unfavorable.

Nature has taught us that immobilization is the prime factor in arresting tuberculosis of the bone. Many an attempt has been made to substitute an artificial fixation to prevent the progress of the disease, with its ravishing results of crippling and terribly deforming the human body.

Early treatment is essential in all cases, whatever method is used, and whatever elements exist.

In the conservative brace methods we have only partial means to accomplish this end. Increasing deformity continues to develop in many cases, until complete invalidism follows, and finally the patient succumbs to this dreadful disease.

In using the brace method it is the exception and not the rule for caries of the spine to be permanently cured; for few cases have actual solid bony union, and without bony union it cannot be considered a cure. These joints, like other joints of the body attacked by tuberculosis, where only fibrous union takes place, are always liable to relapse. It has been pointed out by many men dealing with tubercular infection of the bone that it is very essential to get strong bony ankylosis in order to arrest and cure such lesions, where actual bony destruction has occurred. This rule must be even more strongly applied to the vertebral joints of the spine than to other joints of the body.

Not being able to control the progress of this

most horrible disease, with the distorted bodies constantly in evidence, the profession has been forcibly convinced that a more accurate fixation of the tuberculous spine is essential. Appreciating the leverage action of these vertebræ, and the failure to arrest the disease by external appliances, recourse was had to actual surgical interference. Numerous methods were tried out, as wiring the spinous processes with silver wire, placing a metal bar on each side of the spinous processes, secured by metal or silk sutures. The above attempts were not successful, however. In the last few years the operative treatment of Pott's disease has gained greatly in favor with the surgeons.

CHAPTER XXXVIII.

Bone-inlay Grafts in the Treatment of Pott's Disease.

In using the bone-inlay graft in the treatment of tubercular inflammation of the vertebra there are three recognized methods of indirect autoplastic immobilization of the bodies of the spinal column. The success of these methods depends upon anchoring the spinous process by grafting or placing a transplant of living bone into the spines of the diseased and adjacent living vertebra, thereby fusing, as it were, spines, or posterior portions of the vertebra into a continuous bony mass. The methods are those of Don, Albee and Hibbs.

The location of the disease, the size and shape of the deformity, and the age of the patient, governs the surgeon in selecting such method that is most suitable for each case.

The *"Don"* method (Fig. 112) is limited to the cervical region, because of the anatomical shape, size, and relation of the spinous processes of that location. The *"Don"* operation immobilizes the cervical vertebra affected with tuberculosis by bridging it with a transplant of living bone from the spinous process of the vertebra prominence, and fastening it to the spine of the axis.

An incision is made over the cervical region, exposing the spinous process. The periosteum is

incised and dissected back from the spine of the seventh cervical vertebra to the base of the second. A section of rib is removed, long enough to reach from the seventh cervical to the second cervical spine. The periosteum must always be removed from the convex surface. An opening is made in the broader end of the graft, and fitted

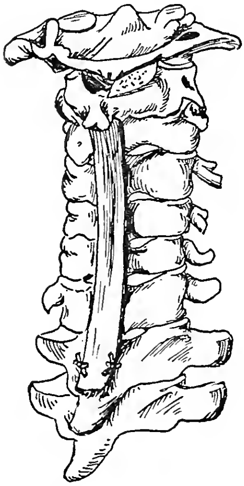


Fig. 112.—Showing the "Don" operation, bridging the cervical vertebræ from the spine of the axis to the spine of the vertebral prominence with an autogenous bone-transplant.

over the spinous process of the vertebral prominence. After placing the section of the rib in the gutter with the convexity forward, the lower end is adjusted to the seventh cervical spine. The upper and lower ends of the graft having previously been perforated, are now firmly fastened to the vertebræ in perfect position, the neck is held in proper position, so that it can be placed

in the groove at the base of the spine of the axis, and sutured with kangaroo tendon to the interspinous ligament, and the soft parts are closed over it.

The after-treatment consists of rest in bed, with sandbags supporting the neck on either side, until the patient can turn the head, or sit up without pain and discomfort. The use of mechanical support is counterindicated, because of the danger of displacing the transplant and discomfort to the patient. By the transplant grafting itself to the spine of the vertebra, immobilization takes place, which gives relief from pain and muscular spasm, and finally to tubercular disintegration.

As a rule, the time required for the convalescence of patient varies from six to eight weeks.

In the technic of Dr. Albee's operation, as modified by the author, a sufficiently long skin incision is made, starting above the diseased area, and curving to one side of the median line, and carried back to the median line, well below the affected area, thus forming a semilunar skin-flap, with its free edge well away from the median line, to avoid having the skin wound directly over the bone repair graft, thus fortifying the grafted area, should any skin or suture infection occur.

Having freed the skin-flap, with its subcutaneous structure, the tips of the spinous processes with the supraspinous ligaments are exposed. As there are no important vessels in this region, hemorrhage is not of much consequence. If need

be the bleeding points are picked up with hemostats and tied, but a hot saline compress is usually sufficient to control any excessive oozing, and prevents blood-clots from forming.

The supraspinous ligament is split over the tips of the spinous processes with a scalpel, divid-

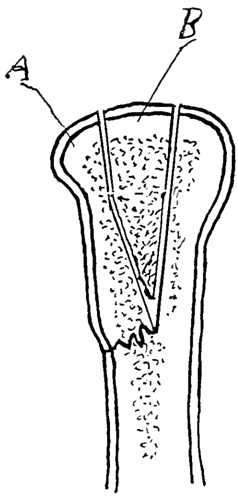


Fig. 113.—Albee's method of splitting the spine of the vertebra perpendicularly, producing fracture of one side (*A*), and showing graft (*B*) in position.

ing them into equal halves. The intraspinous ligaments are also split, care being exercised further not to cut any of the muscular ligamentous attachments to these spinous processes. Then, with a sharp osteotome, 1½″ wide, the spinous processes are split to a depth of from ⅓″ to ⅔″. One-half of each spinous process is always fractured completely on the same side at its base, and set over a distance varying according to the thick-

ness of the graft which is to be implanted. All bleeding should be controlled before the wound is closed.

It rests with the operator to determine the size and thickness of the graft to be used in each case, taking into consideration the segment of the spine to be grafted and the amount of strain the graft must endure. In general, the thickness of the graft should include the total thickness of the tibial cortex, including the four following different tissues: periosteum, endosteum, cortex, and marrow substance.

The graft-bed once prepared presents on one side of the gutter the incised surface of the unbroken halves of the spinous processes, and in the interval between these processes are the cut surfaces of the halves of the supraspinous and interspinous ligaments, with their bone attachments undisturbed. The opposite wall of this gutter is formed by the incised surfaces of the fractured halves of the spinous processes, with their portions of supraspinous and interspinous ligaments undisturbed, as in the opposite side of the gutter. The full leverage of the spinous processes as posterior arms of vertebral levers has been largely preserved.

In this connection it should be appreciated that the spine is made up of a distinct number of levers, and that each and every vertebra is an individual lever, with its fulcrum at the lateral facets, and that its anterior arm is the vertebral body; the posterior arm is the spinous process.

The length and shape of the required graft is determined by the author's caliper knives and a piece of sheet lead or a flexible probe applied to the gutter-bed, and used as a pattern to shape the graft. The bed is covered with plain gauze until the graft has been removed from the tibia.

Removal of the Graft. With the patient still lying on the stomach, the leg from which the graft is to be removed is raised from the table, and flexed to an acute angle on the thigh, which brings the anterior portion of the leg in good position for removal of the graft. A generous skin incision is made along the anterointernal surface of the tibia, sufficiently long to allow a free exposure of such portion of the tibia as is desired for the removal of the transplant, and so placed that its closure will not bring the skin sutures over the bone cavity produced by the removal of the graft. The skin is dissected up from the periosteum, which is left undisturbed, and the muscles attached to the crest of the tibia carefully dissected away. The pattern of the required graft is outlined by incising the periosteum with the author's caliper knives, using the moulded piece of sheet lead or a probe as a pattern. The graft is taken from the lower internal surface of the tibia shaft; this part is, as a rule, sufficiently broad, and furnishes a cortex-transplant stronger and denser than the upper portion of the bone.

If the graft is to be straight, it is best removed from the crest, wide enough to encroach upon the antero-internal surface of the tibia, that

the central or fulcrum portion of the curved graft includes the crest of the tibia, and each end is cut obliquely across the antero-internal surface. The advantage of the graft secured in this way includes at its fulcrum portion, the dense and thick cortical bone of the crest. This is quite essential, because the strength of any lever is dependent upon the strength of its fulcrum portion.

It has been found that kyphoses, sharply angular, and of short duration, especially in children, can be corrected to a certain degree. This fact should be taken advantage of in cutting the graft to conform to such amount of correction.

After preparing the gutter or bed, the spine is brought as near normal condition as possible by cautious manual pressure on either side over the lateral masses, while the curve of the spine thus corrected is obtained by fitting the piece of sheet lead or probe into the groove of the split spinous processes.

The technic is carried out as above described, with the addition, however, of the pressure used in relieving the deformity, while the bone-pegs or kangaroo tendon sutures are being put in place to hold the graft in position.

The straight graft is procured by cutting the tibial cortex through near to the medullary cavity with the motor saw, following the periosteal outlines already made; this includes the saw cut just to the outer side of the tibial crest (Fig. 114), and at a right angle to the one already made on the antero-internal surface. This cut must be made

the whole length of the graft, if a straight one; if a moulded one, only to include the middle or fulcral portion. At either end, beyond this central or crest portion, the graft outlines the marrow-cavity, and the saw-cuts therefore need only come on the antero-internal surface of the tibia.

At both ends of the graft a saw-cut is made with a very small motor saw, or a number of drill-holes are made, and finally a sharp osteotome or chisel is used to finish freeing the graft from

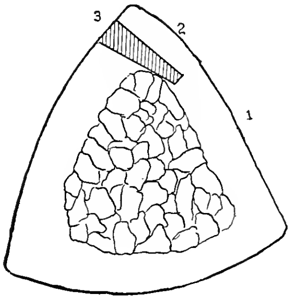


Fig. 114.—Position from which to remove the graft to be used in a case of Pott's disease where there is marked kyphosis, graft being bent to fit the curvature by saw cuts. *1*, indicates the outside of the tibia; *2*, the undisturbed crest; *3*, the location from which to remove graft. This location gives the best possible cortical transplant.

the tibia. It is now grasped with the author's graft-retaining forceps, then loosened with a thin osteotome, which is forced into the longitudinal saw-cuts, and pried free and placed in the previously prepared bed. "In order to be entirely and continuously successful, the motor saw is indispensable in removing the graft; especially is this true in adult cases," "as the bone is very

dense and brittle," and, even with the greatest of care, the bone is at times cracked, or the graft broken and rendered unfit for use. The chisel method is not only slow and bunglesome, "but the constant blow of the mallet on the chisel traumatizes the graft, and does not permit of its accurate moulding." Pain in the part operated has also been observed to be much less since the motor instruments have been perfected for this use.

Fixation of the Graft in Position. If the graft is a straight one, it is held in place by bone-pegs passing through the graft and the split spinous processes, or by kangaroo tendon, by first passing a strong suture through one-half of the split supraspinous ligament at one side of the gutter; then the suture is passed up over the graft at the middle portion, and through the other split half of the supraspinous ligament opposite. This suture is drawn taut and tied, thus approximating the two halves of the split supraspinous ligament over the graft at its central portion. The ends are next secured in the same manner, always endeavoring to pass the suture as deeply as possible, so as to get a firm hold upon the ligament and close to the spinous processes, either above or just below them. This gives firm contact of the graft to the separated halves of the split spinous processes. In the Albee method only kangaroo tendon is used.

In certain cases it is advisable to place the suture either in the supraspinous ligament, half way between the spinous processes, or at a vary-

ing distance to the sides of these processes, in order that the ligament may yield, and the transplant be completely covered. In the lumbar region, especially in adults, the supraspinous liga-

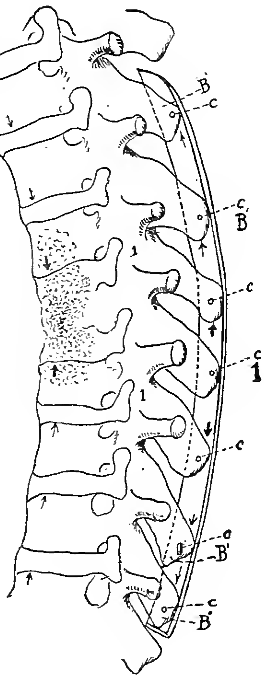


Fig. 115.—Modified Albee's method of placing bone-graft in spine for the cure of Pott's disease. *c,* indicates bone-pegs used in holding inlay in position. *Arrows* on body of vertebræ show direction of force of weight and muscular spasm, which causes crushing of diseased bodies of the vertebræ. *1,* indicates the first vertebræ involved; [1] vertebræ secondarily involved; *B,* the healthy vertebra above and below diseased ones.

ment may be so dense and tense that it is difficult on account of the required thickness of the graft to cover it as it should be, unless the verte-

bral aponeurosis is incised on either side, just external to the line of sutures. This permits a separation of the ligament sufficient to cover the graft.

Before the two ends of the transplant are securely fastened in position, it should be made certain that the inlay graft reaches far enough beyond the diseased vertebra, both above and below, to include at least one or two spines of healthy vertebra. It should be emphasized to have the graft reach low enough, because of the natural obliquity of the spinous processes in certain segments of the vertebral column, as in the thoracic region; the tips of the diseased vertebra are well below their corresponding bodies, so they may somewhat mislead, and the applied graft may be moulded too short, and not include the healthy vertebral spines below and above. The sharp posterior corners are removed by the Rongeur forceps, and these bone chips are placed about and under the graft ends before tying the graft end sutures, or making holes through the spines and the inlay, with the 1/8″ motor drill, in which the bone-pegs are placed. The graft ends should be sure to contact with the spinous processes. The small fragments of bone so placed furnish added foci for bone-proliferation, so it is more certain to amalgamate the graft ends to the contacting processes; this being borne in mind, Macewen pointed out that the bone-graft varies in its osteogenesis in inverse ratio to its volume. In other words, the smaller the graft, the greater its compara-

tive surface, and the more active its bone-growing ability. It has been further demonstrated that small grafts, because of their size, obtain their nourishment more readily from their surrounding serum and blood, and a periosteal covering is essential for continued success. The author has occasionally found that kangaroo tendon breaks, and he has added to the fixation of the graft bone-pegs, placing one through each spinous process, above and below the diseased vertebra. Kangaroo sutures are introduced at intervals of ½″, and are now passed in similar manner as the sutures mentioned above, until the entire length of the graft is closed in, and, with the addition of the bone-pegs, firmly secures the graft in position. In making the transverse saw cuts to allow the graft to bend, it is accomplished in the same manner as a carpenter cuts a board to cause it to bend about a curved surface. The graft is held securely by the operator with two of the author's graft retaining forceps, one at either end, the motor being held firmly against the instrument table, and the saw overhanging the edge. The uniform depth of the saw-cuts is regulated by placing the right guard on the saw, in accordance with the thickness of each graft. This simplifies matters, as the surgeon has no fear of entirely severing the graft, and the saw cuts to the same depth at each point. With the *Geiger* saw, it is not necessary to use saline solution to prevent burning the bone, as the speed of the saw is very slow; this is an important point, as water or solution of any kind is especially objectionable in bone surgery.

In the application of the curved graft, the surface (bearing the transverse saw-cuts) naturally lies next to the gutter-bed, with the periosteal surface posteriorly. The edges of this graft contact with the cut surface of the gutter. The same method is adopted in the application of the sutures as is used in securing the other shaped grafts, with the exception that the bent-in graft is completely sutured into position at one end, while the other end projects ready to be bent in, and the interrupted sutures are then inserted consecutively until the projecting end of the graft is reached, and the placing of the imbedding suture is complete.

If the bent-in graft is held by one imbedding peg or suture applied at each end, holding it bent into position while the other pegs or sutures are added, the graft is in danger of fracturing through one of its transverse saw-cuts. In any case, whether this fracture of the graft occurs or not, it is well to reinforce this graft by placing along each of its sides, at the maximum point of curvature, thin strips of cortical bone, cut with the motor saw, from the tibia where the graft is obtained.

The skin is closed in the usual way, and plain sterile dressings are applied. Thick pads of gauze and cotton, varying in thickness according to the degree of the kyphosis, are placed to prevent pressure-necrosis on the apex of the grafted kyphosis. The dressings and pads are then securely fastened in place by strips of zinc oxide adhesive plaster, 1½″ to 2″ wide.

The postoperative care of these cases consists in recumbent posture on the back on a fracture-bed for five weeks in adult cases, and six weeks for children, with no more restraint than that afforded by pinning a towel about the chest, to which are attached four strips of broad muslin bandages. Two strips are pinned to the upper side of the encircling towel in front, to be secured to each side of the mattress of the bed above the shoulders. The remaining two strips of bandage are fastened to the encircling towel near its lower edge, and to the two sides of the mattress at the foot end of the bed. These restraining bandage-strips are so placed to prevent the patient from attempting to sit up or roll from side to side, and are, as a rule, only necessary in children; adult patients usually lie recumbent without restraint.

Where the spine presents marked kyphosis, it is necessary to apply thick, soft pads on each side of the spine, before placing the patient on his back, or when there is an excessive deformity it is best to secure the patient in bed, lying upon his side to obviate undue pressure on the grafted area, in this way preventing necrosis of the skin-flap.

The slight amount of motion produced by respiration is not detrimental to the adhesion of the graft, but rather is considered a stimulant to callus formation between the contacting cut surfaces of the bone, thus hastening the fixation or grafting of the transplant to the spinous processes.

It should be observed that the application of

the bone-graft, for the purpose of ankylosing the affected vertebra, accomplishes the long-sought-for immobilization of these diseased joints; but it does not directly remove the disease itself, which is an impossibility. However, as ankylosis of other tuberculous joints has proven so satisfactory in arresting the disease without requiring the removal of all affected bones, so in case of tuberculous infection of the vertebral joints, ankylosis acts with even greater advantage in that by the bone-graft implanted in the spinous processes the vertebræ are not only ankylosed, but their diseased bodies can be separated, thus removing active causation-elements in the extension of the disease. Although as a rule, the patient is immediately relieved from symptoms and evidence of active disease, he should have the general bodily rest, nourishing foods, sunlight, and fresh air, which have always been found of such great importance in these cases.

It is advisable in these cases that six months or more of postoperative convalescence shall have passed before the patient resumes active or heavy work. Children should have at least a year of restraint from general activity, with daily rest-periods, and out-of-door life. It proves very beneficial in these cases, following the five to six weeks postoperative confinement in bed, if they can be removed from the city to the mountains or sea-shore, where the surroundings are more healthy. In other words, they should be managed in a similar way to cases suffering from lung or

glandular tuberculosis; this should be carried out in every detail.

As a rule, Dr. Albee has followed the practice of not applying external fixation to the spine after his operation. There are exceptions, however, where for definite reasons it has been deemed advisable to have the patient wear a spinal brace or a plaster-of-Paris jacket for varying lengths of time after the five or six weeks of immediate postoperative fixation in bed; for example, where the patient is obliged to leave the hospital before the prescribed period of five or six weeks in bed has elapsed; or in cases where a marked kyphosis in the dorsal region has developed before the operation, necessitating a temporary weakening of the graft by transverse saw-cuts in order to bend it into place. In addition, such a graft is subjected to strain varying according to the severity of the kyphosis. In these cases, a plaster-of-Paris jacket is advisable for a few months, or a longer period of the recumbent posture.

The natural leverage action of each vertebra is not lost by the application of the bone-graft, but is changed from a crushing together of the bodies anteriorly to a pulling of the ankylosed spinous processes on the ankylosing graft posteriorly. The change from the crushing effect takes place in the bodies by the approximation of the anterior arms of the levers, to a traction effect through the long axis of the graft implanted in the ends of the posterior arms of the levers, preventing up-and-down motion of the spinous processes. The

fulcra of these levers remain constant. In comparatively early cases, where sharply angular anteroposterior deformity of the spine exists, further progress of the kyphosis can be prevented, and some correction maintained, by bone-transplantation. Besides accomplishing this, the immobilization of the involved segments of the spinal column is secured without marked interference with body activity, or respiratory function, and does away with the long protracted palliative treatment ordinarily resorted to.

Fixation is indicated in all cases and at all ages where pain or muscle-spasm demands it, and the earlier the operation the more favorable the prognosis; it is essential for the prevention as well as for the correction of deformity, and is even more urgently demanded in the presence of complications, such as psoas-spasm, tubercular cyst, or paraplegia.

The only two contraindications are, the inability to secure a clean field for operation, and the debilitated condition of the patient. The first, however, is rare, as a tubercular cyst seldom points to or invades the region of the spinous processes. Uninfected tubercular cysts between the spinous processes have not interfered with the primary union of the graft when encountered unexpectedly in implanting the graft, and cases can be cited where bone-grafts have spanned through these tubercular cysts with no detriment to the graft or delay in its bony union.

The second condition does occur occasionally,

and when it does, the patient's system should be built up before operating.

Prognosis in all operative cases is favorable as to relief of all symptoms, and some decrease in the deformity. Correction of the deformity is largely overcome in children, if operated upon early; and in cases of longer duration, where the kyphosis is sharply angular, or presents a considerable amount of motion, a certain amount of correction can be obtained. The prognosis is governed by the patient's postoperative environments and daily conduct, and is all-important. Rest, forced feeding, fresh air, and exposure to sunlight, are the essential elements of the after-treatment.

CHAPTER XXXIX.

Hibbs' Operation for the Cure of Pott's Disease.

"Hibbs'" operation (Fig. 116) consists in bringing about a fusion of the posterior portions of the vertebra, thus preventing pressure on, and

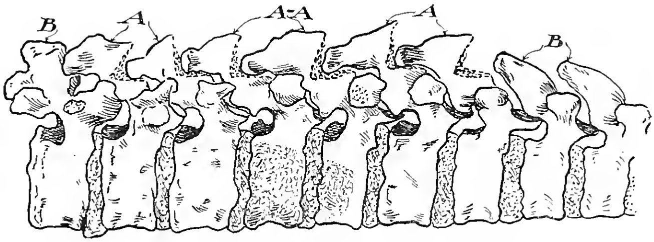


Fig. 116.—Hibbs' operation for the cure of Pott's disease. *AA*, two bodies of the vertebræ diseased; *A*, two healthy vertebræ above and below the diseased vertebræ; *B*, vertebræ not operated upon.

motion of, the vertebra that is undergoing tubercular disintegration.

After placing the patient in a ventral position, a longitudinal incision is made over the diseased vertebra, exposing the spinous processes and the lamina. The spinous processes are broken at their base with a chisel, and so placed that the tip of each one is in apposition or lying on the broken base of the process immediately below it. As in all other operations for tuberculosis of the spine,

one or more spines of the healthy vertebra above and below the diseased vertebra must be included in the fixation. The periosteum is pushed back from the adjacent edges of the lamina to their ventral side, after its removal from their posterior surface. A small spicula of bone chiseled from the lamina is placed transversely across the space between them, its free end lying in contact with the lamina next below.

In closing the wound, we bring the periosteum superspinous and interspinous ligaments over the fragments by interrupted kangaroo tendon or iodized gut sutures. The skin is closed with plain gut, subcuticular, over which a sterile dressing is applied, which is held in position with 1″ straps of adhesive, an inch apart.

The postoperative treatment consists of absolute rest in bed for eight weeks, after which time the patient may be propped up in bed with back-rest for four weeks. A well-fitting brace or plaster-of-Paris cast is applied at the end of twelve weeks. After this the patient is gradually permitted to resume the erect posture, and then is allowed to take moderate exercise. At the end of sixteen weeks the brace or cast is gradually removed. This operation induces the permanent callus, binding together the fragments and the posterior parts of the vertebra dealt with. It prevents motion in the vertebral articulations, immobilizing indirectly, the diseased vertebral bodies, thereby relieving the symptoms and arresting the onslaught of the disease.

By this ingenious operation, Dr. Hibbs has reported a great number of cases of Pott's disease successfully operated on in the New York Orthopedic Hospital.

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